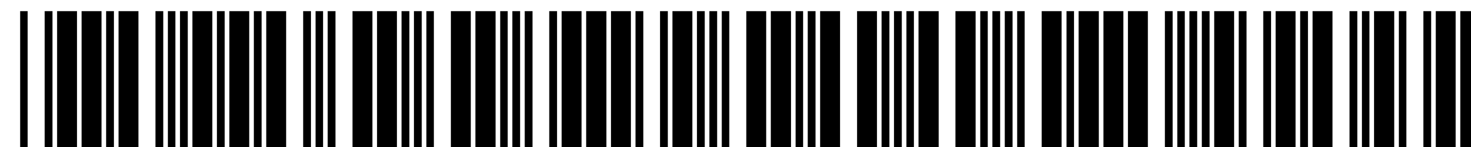


(12) **United States Patent**
Friedman et al.

(10) **Patent No.: US 7,806,643 B2**
(45) **Date of Patent: Oct. 5, 2010**

(54) **ELEVATOR-BASED TOOL LOADING AND BUFFERING SYSTEM**

(75) Inventors: **Gerald M. Friedman**, New Ipswich, NH (US); **Michael L. Bufano**, Belmont, MA (US); **Christopher Hofmeister**, Hampstead, NH (US); **Ulysses Gilchrist**, Reading, MA (US); **William Fosnight**, Carlisle, MA (US)

(73) Assignee: **Brooks Automation, Inc.**, Chelmsford, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 470 days.

(21) Appl. No.: **11/210,918**

(22) Filed: **Aug. 23, 2005**

(65) **Prior Publication Data**

US 2006/0099054 A1 May 11, 2006

Related U.S. Application Data

(60) Provisional application No. 60/604,099, filed on Aug. 23, 2004.

(51) **Int. Cl.**
B65H 1/00 (2006.01)
B65G 65/00 (2006.01)

(52) **U.S. Cl.** **414/222.01**; 414/277; 414/217; 414/940

(58) **Field of Classification Search** 414/277, 414/282, 217, 217.1, 940, 222.01, 222.13; 104/127; 901/21
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,693,770 A * 11/1954 Hubscher 104/128
4,465,174 A * 8/1984 Uhl 198/361
4,724,874 A 2/1988 Parikh et al. 141/98
4,995,430 A 2/1991 Bonora et al. 141/98
5,032,053 A * 7/1991 Krieg 414/278
5,097,421 A 3/1992 Maney et al. 364/48
5,370,491 A 12/1994 Bonora et al. 414/217
5,611,452 A 3/1997 Bonora et al. 220/378
5,927,926 A * 7/1999 Yagi et al. 414/280

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1 202 325 5/2002

(Continued)

OTHER PUBLICATIONS

Campbell, "Overhead Intrabay Automation and Microstocking—a virtual fab case study," *IEEE/SEMI Advance dSemiconductor Manufacturing Conference*, pp. 368-372 (1997).

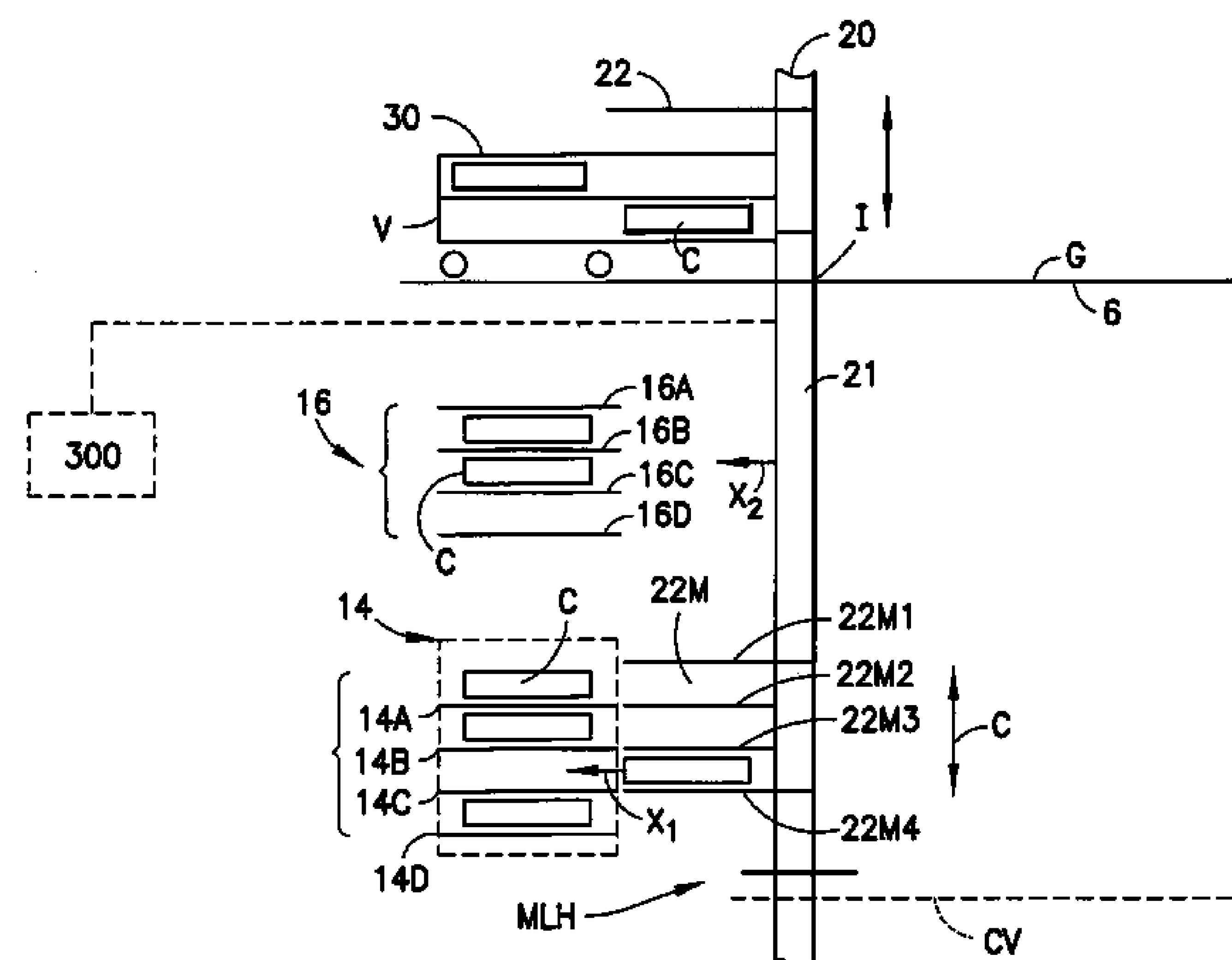
(Continued)

Primary Examiner—Gregory W Adams
(74) *Attorney, Agent, or Firm*—Perman & Green, LLP; Richard Pickreign

(57) **ABSTRACT**

A substrate processing apparatus is provided. The apparatus has a casing, a low port interface and a carrier holding station. The casing has processing devices within for processing substrates. The load port interface is connected to the casing for loading substrates into the processing device. The carrier holding station is connected to the casing. The carrier holding station is adapted for holding at least one substrate transport carrier at the load port interface. The carrier holding station is arranged to provide a fast swap section for replacement of the substrate transport carrier from the carrier holding station.

11 Claims, 34 Drawing Sheets



U.S. PATENT DOCUMENTS

5,980,183	A	11/1999	Fosnight	
5,988,233	A	11/1999	Fosnight et al.	141/63
6,068,437	A	5/2000	Boje et al.	
6,079,927	A *	6/2000	Muka	414/217
6,113,341	A	9/2000	Fukushima	
6,129,496	A *	10/2000	Iwasaki et al.	414/222.01
6,183,184	B1	2/2001	Shiwaku	
6,283,692	B1	9/2001	Perlov et al.	414/222.01
6,354,781	B1 *	3/2002	Pan	414/217
6,438,623	B1 *	8/2002	Ryan	710/2
6,453,574	B1	9/2002	Chen	
6,457,928	B1 *	10/2002	Ryan	414/281
6,506,009	B1 *	1/2003	Nulman et al.	414/217.1
6,517,304	B1 *	2/2003	Matsumoto	414/217
6,572,321	B1 *	6/2003	Nulman	414/416.05
6,579,052	B1 *	6/2003	Bonora et al.	414/222.01
6,604,624	B2	8/2003	Hirata et al.	
6,641,350	B2 *	11/2003	Nakashima et al.	414/217
6,681,916	B2 *	1/2004	Hiroki	198/347.1
6,695,120	B1	2/2004	Trammell	
6,726,429	B2	4/2004	Sackett et al.	
6,745,102	B1 *	6/2004	Liu	700/228
6,881,020	B2	4/2005	Chang et al.	
2003/0156928	A1	8/2003	Sackett et al.	
2003/0198540	A1	10/2003	Lin et al.	
2004/0149672	A1 *	8/2004	Motoori et al.	212/332

FOREIGN PATENT DOCUMENTS

JP	10-45213	2/1998
JP	2000-53237	2/2000
JP	2000-289975	10/2000
JP	2001-31216	2/2001
WO	WO 00/37338	6/2000
WO	WO 01/13408	2/2001
WO	WO 01/96884	12/2001

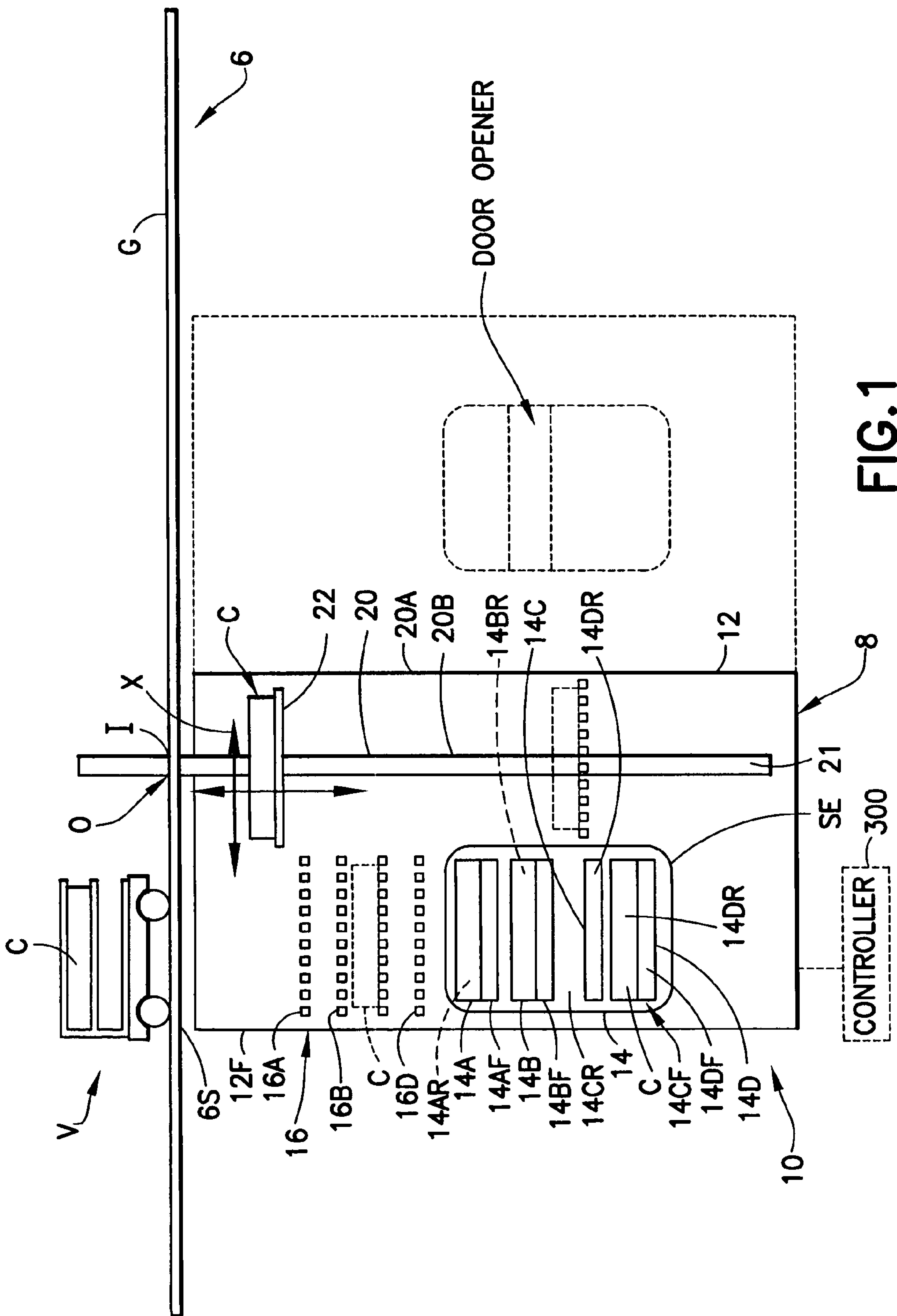
OTHER PUBLICATIONS

Kaempf , "Automated Wafer Transport in the Wafer Fab," *IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, pp. 356-361 (1997).

Kuo, "Modelling and Performance Evaluation of an Overhead Hoist Trasnport System in a 300 mm Fabrication Plant," *Int. J. Adv. Manuf. Technol.*, vol. 20, pp. 153-161 (2002).

Sikich, "Development and Implementation of an Automated Wafer Transport System," *IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, pp. 400-404 (1998).

* cited by examiner


DOOR OPENER
CONTROLLER
FIG. 1

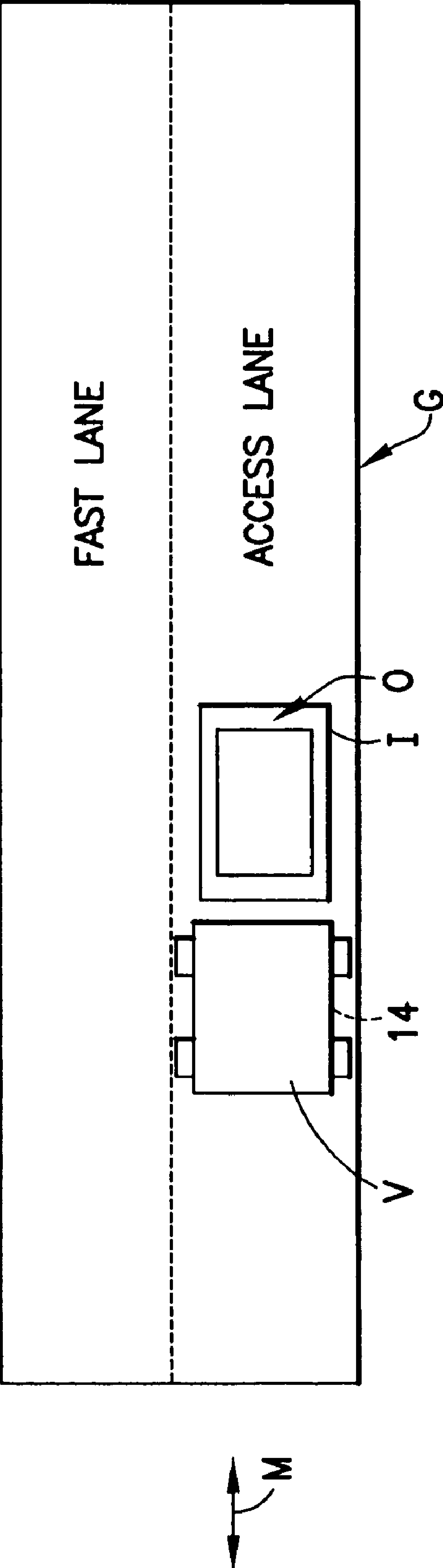


FIG.1A

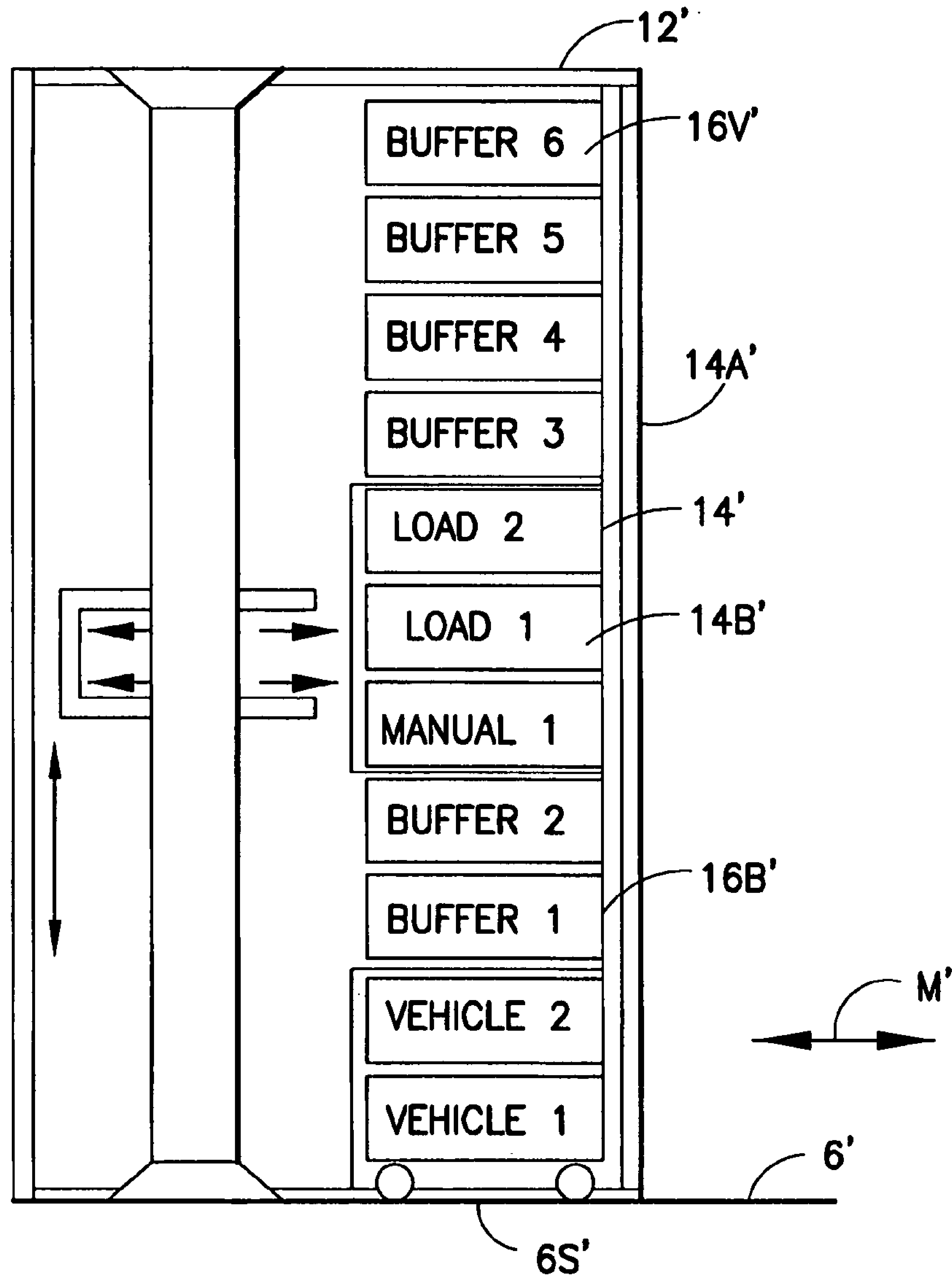


FIG.2A

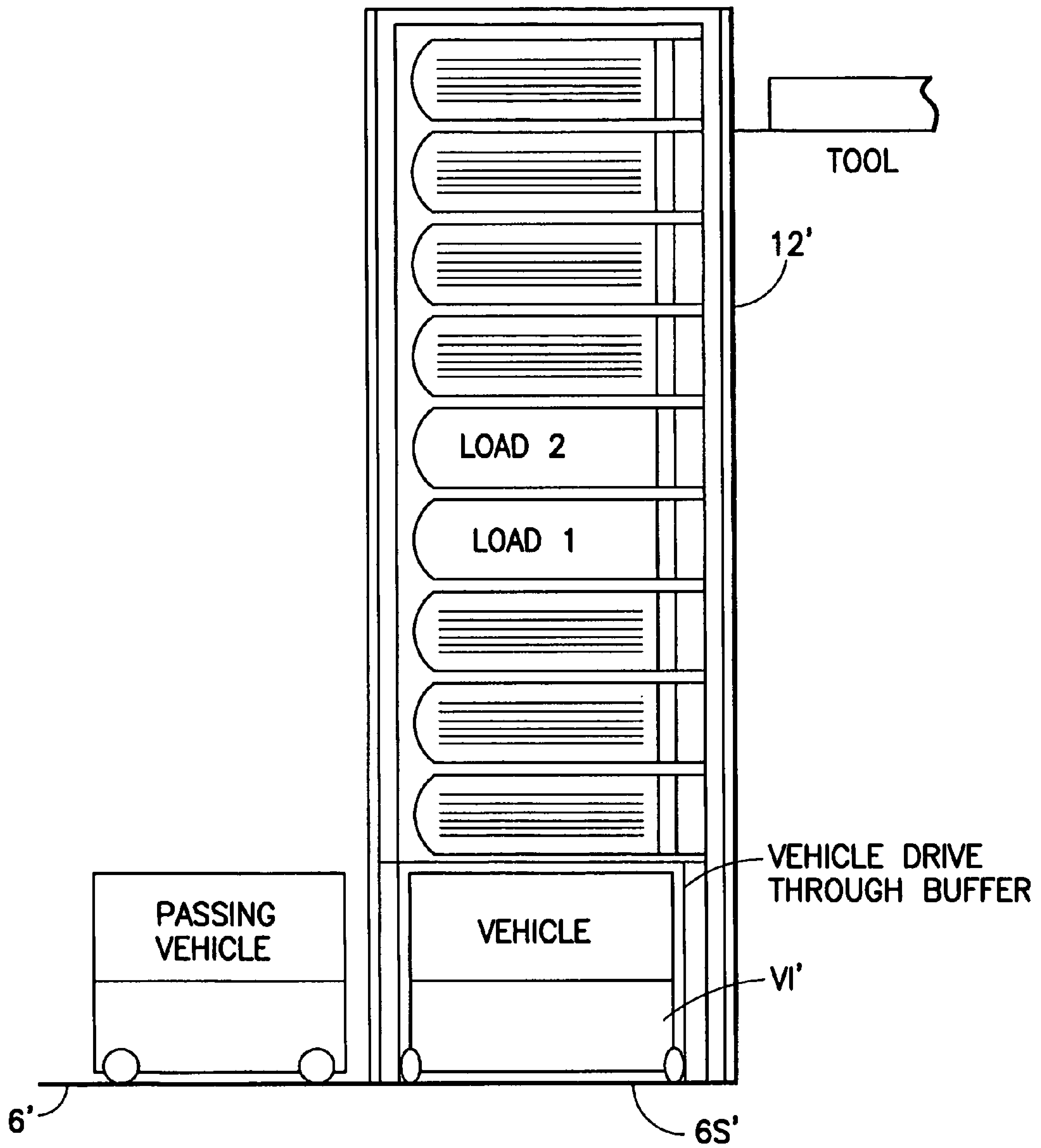


FIG.2B

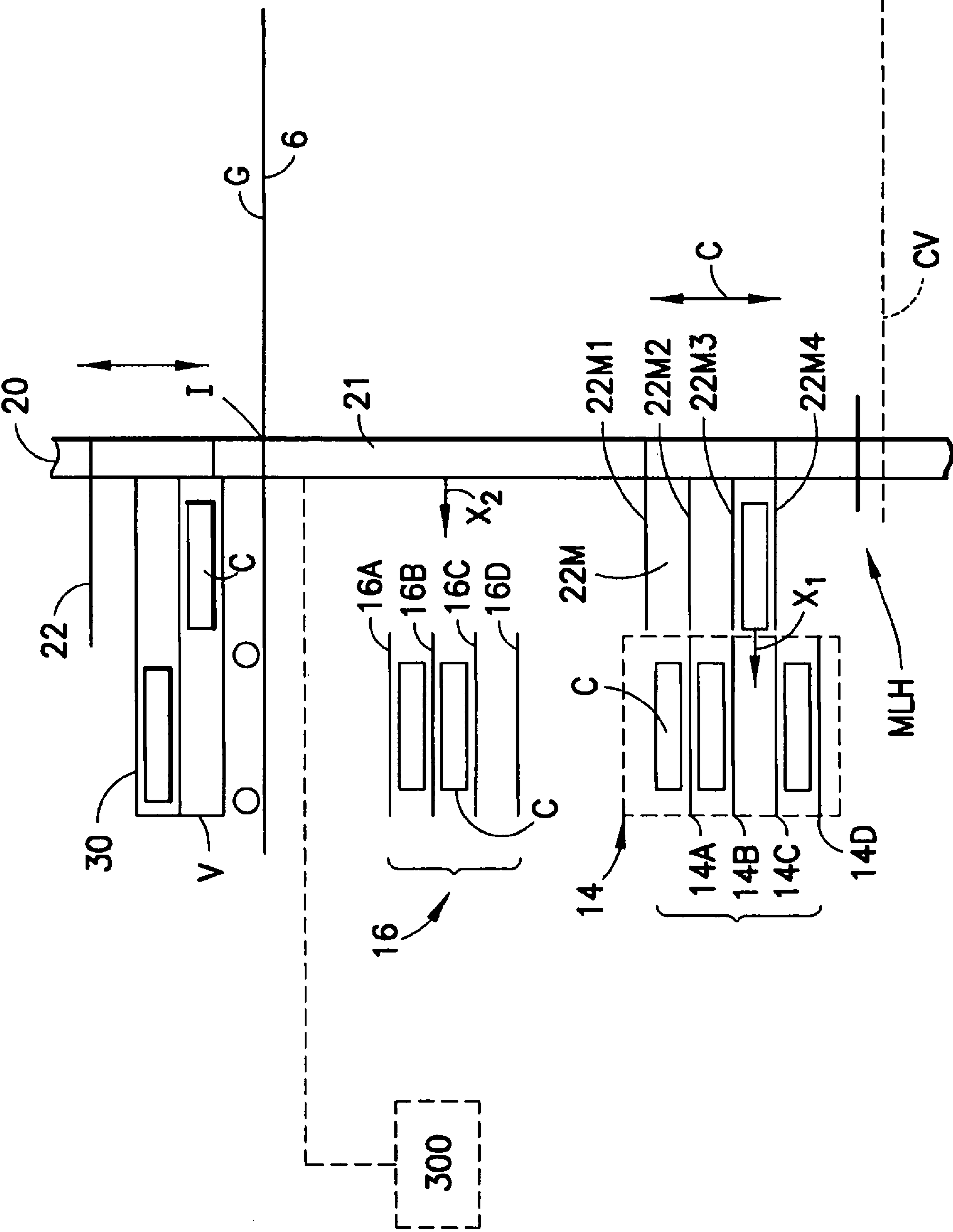


FIG.3

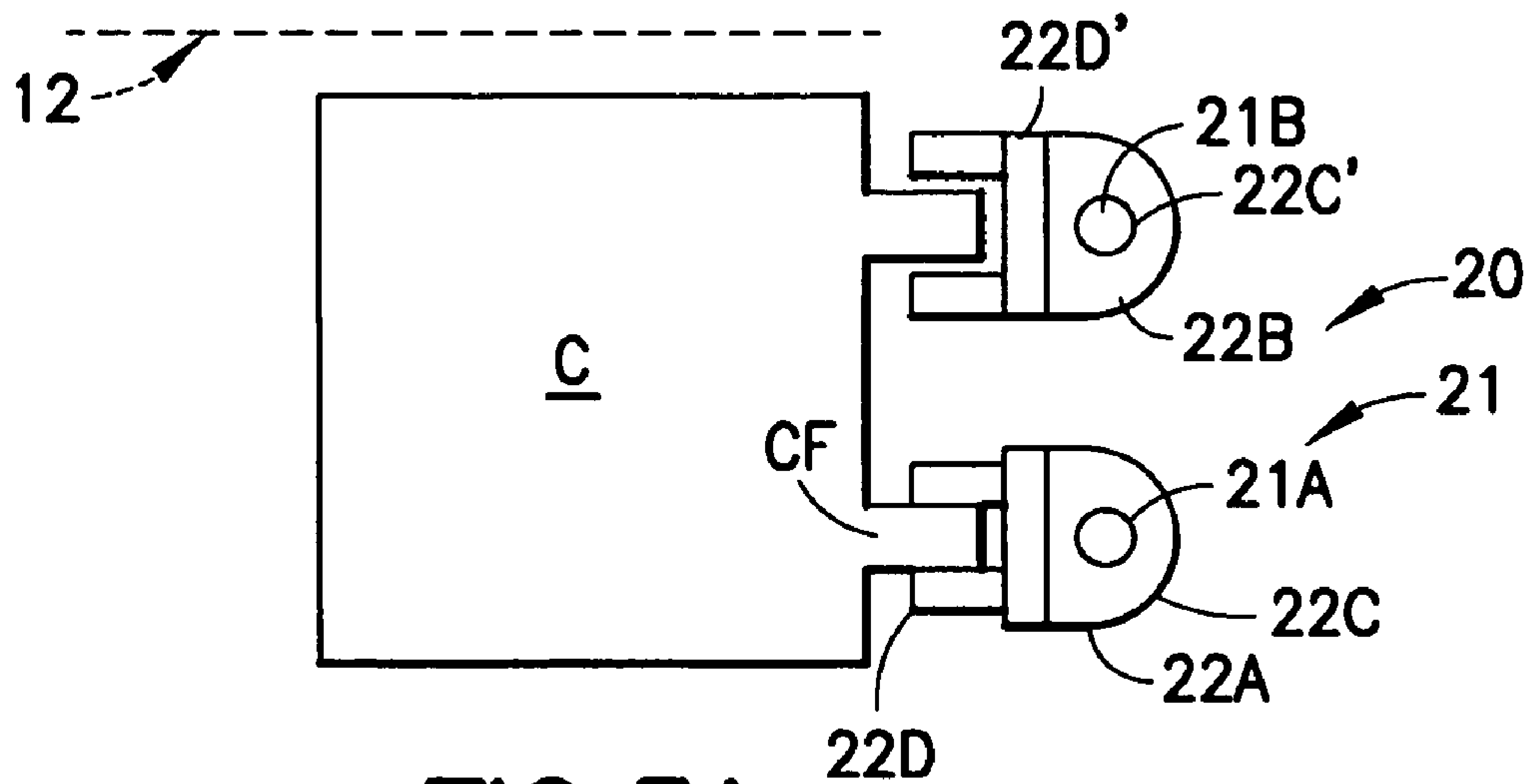


FIG.3A

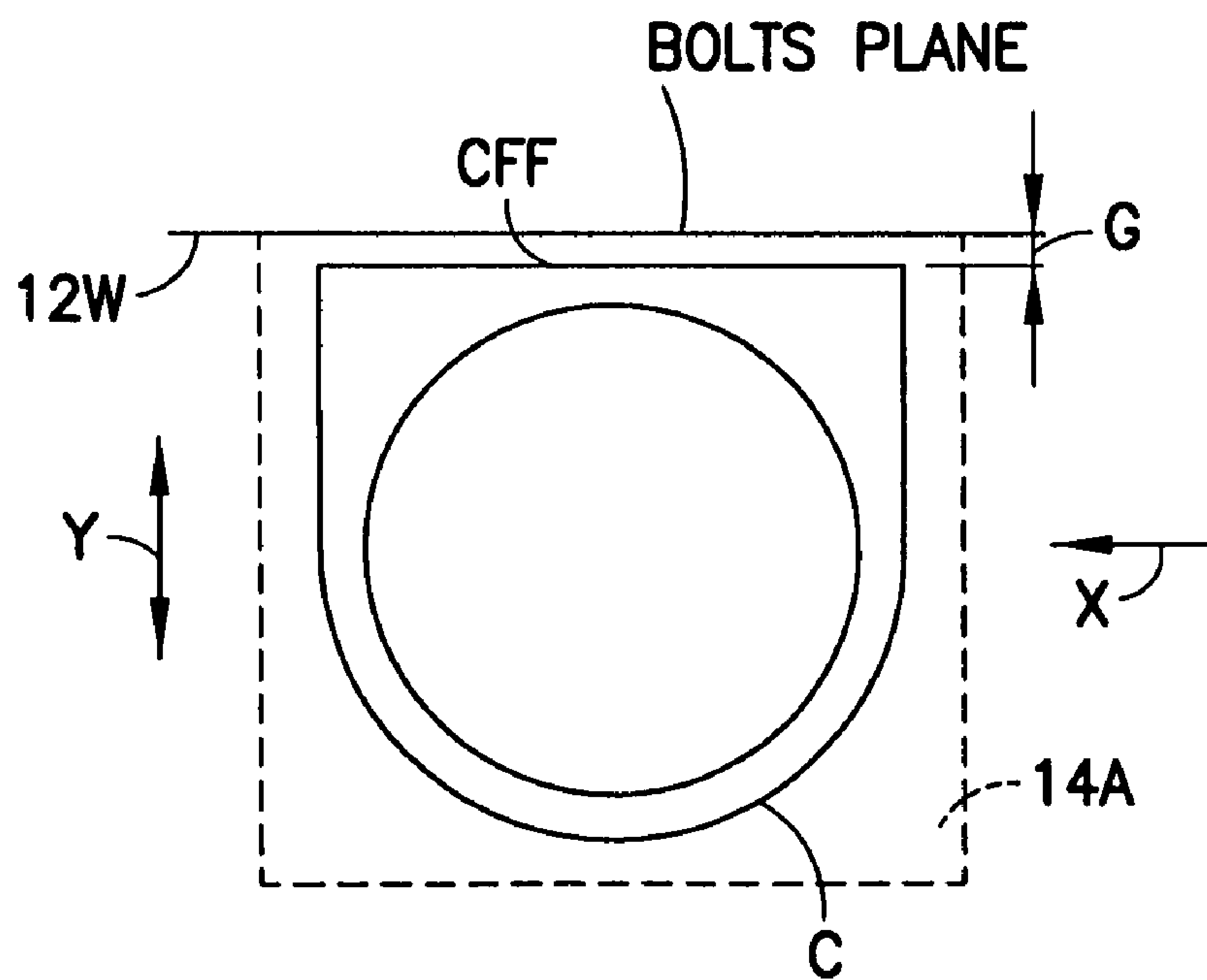


FIG.7

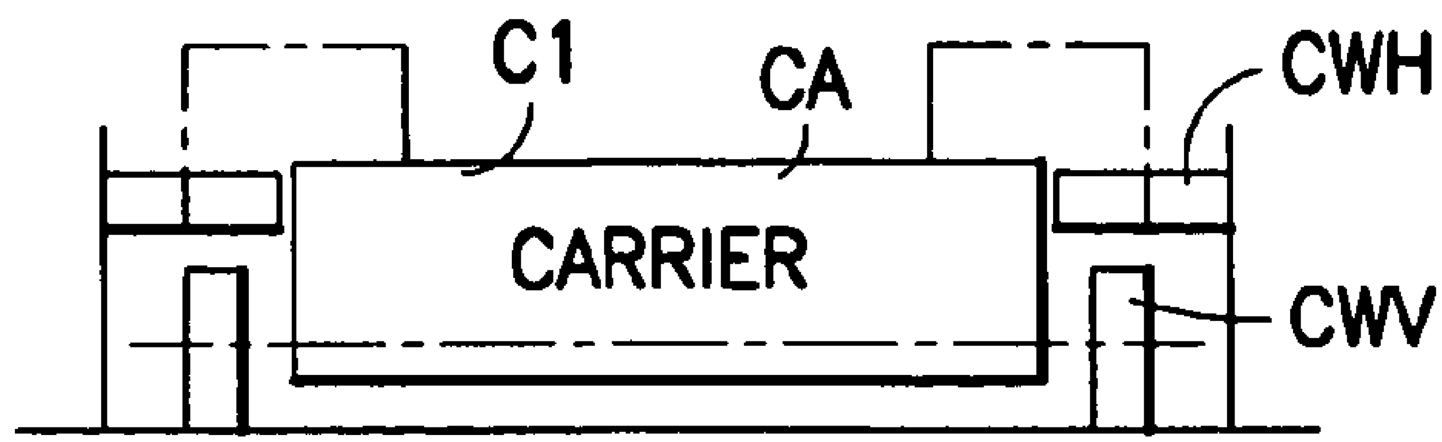


FIG.4A

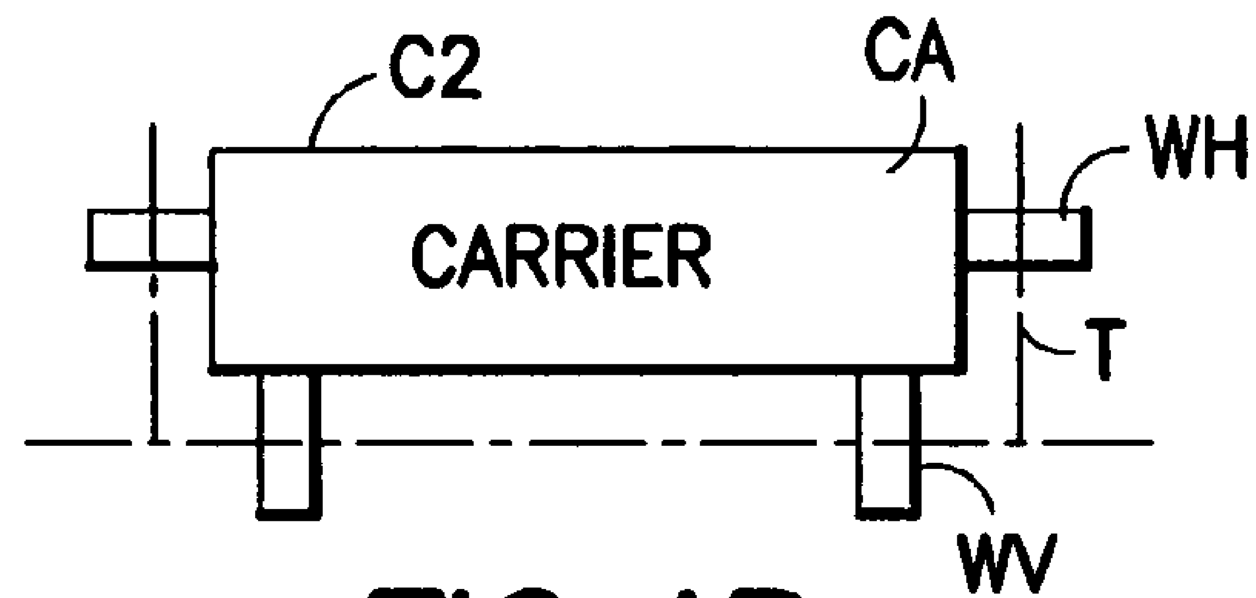


FIG.4B

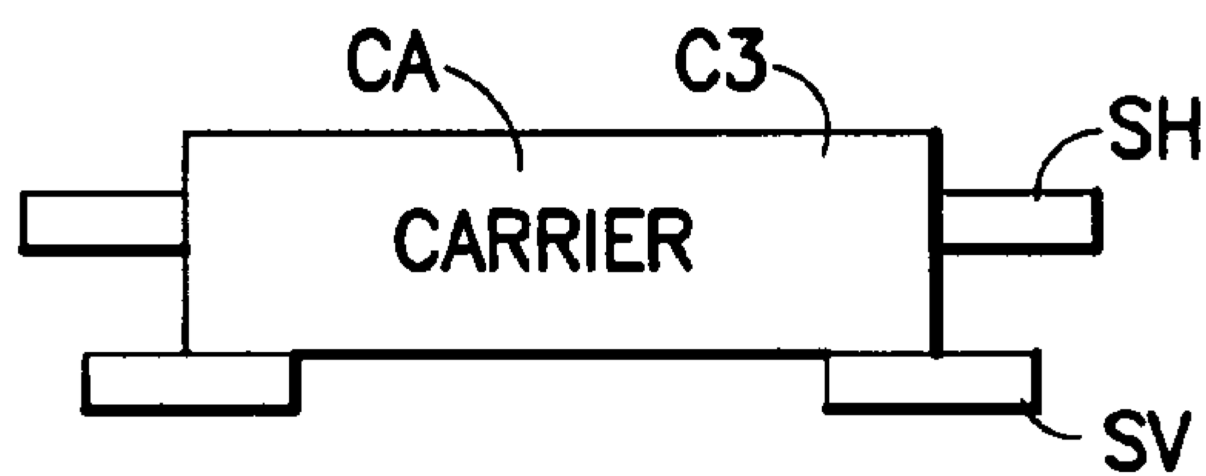


FIG.4C

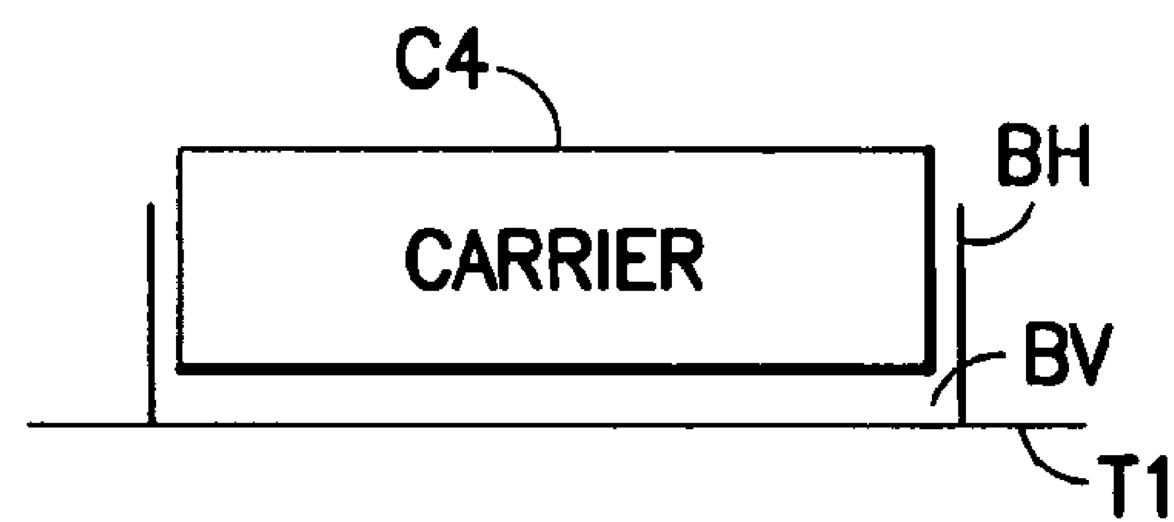


FIG.4D

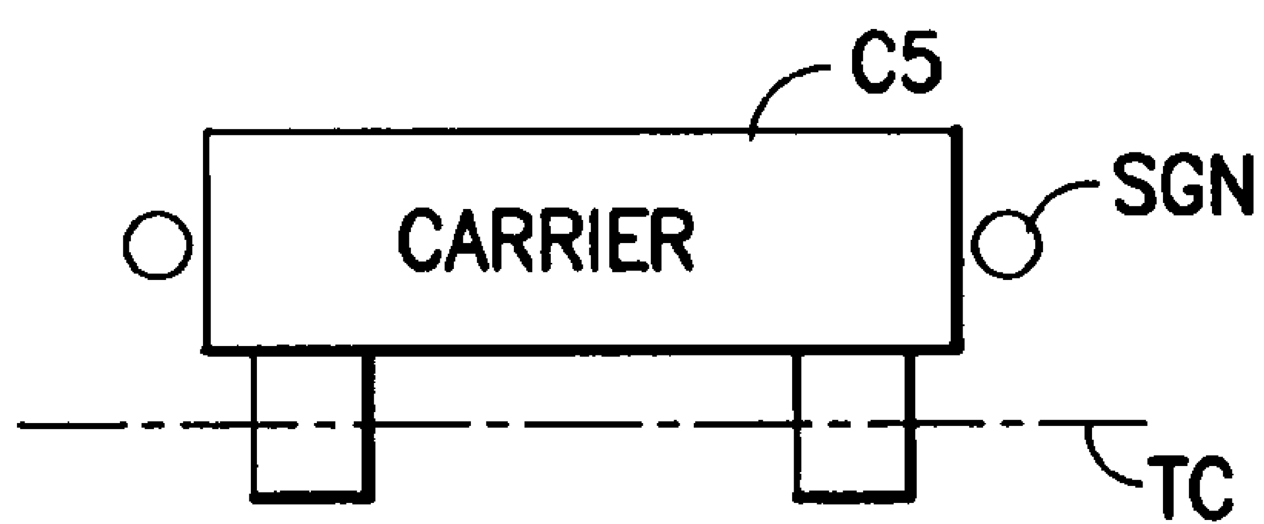


FIG.4E

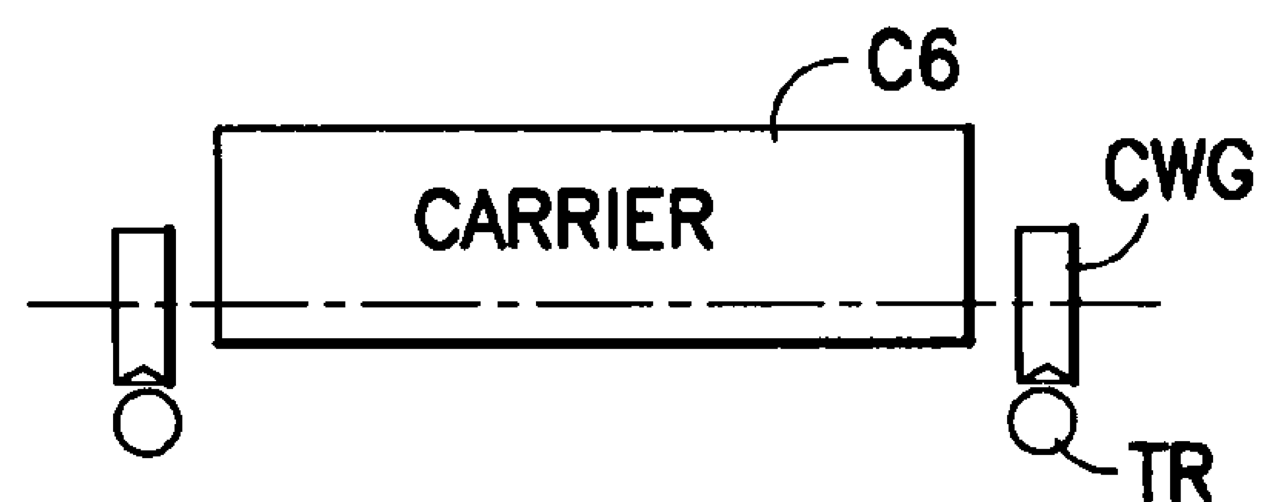


FIG.4F

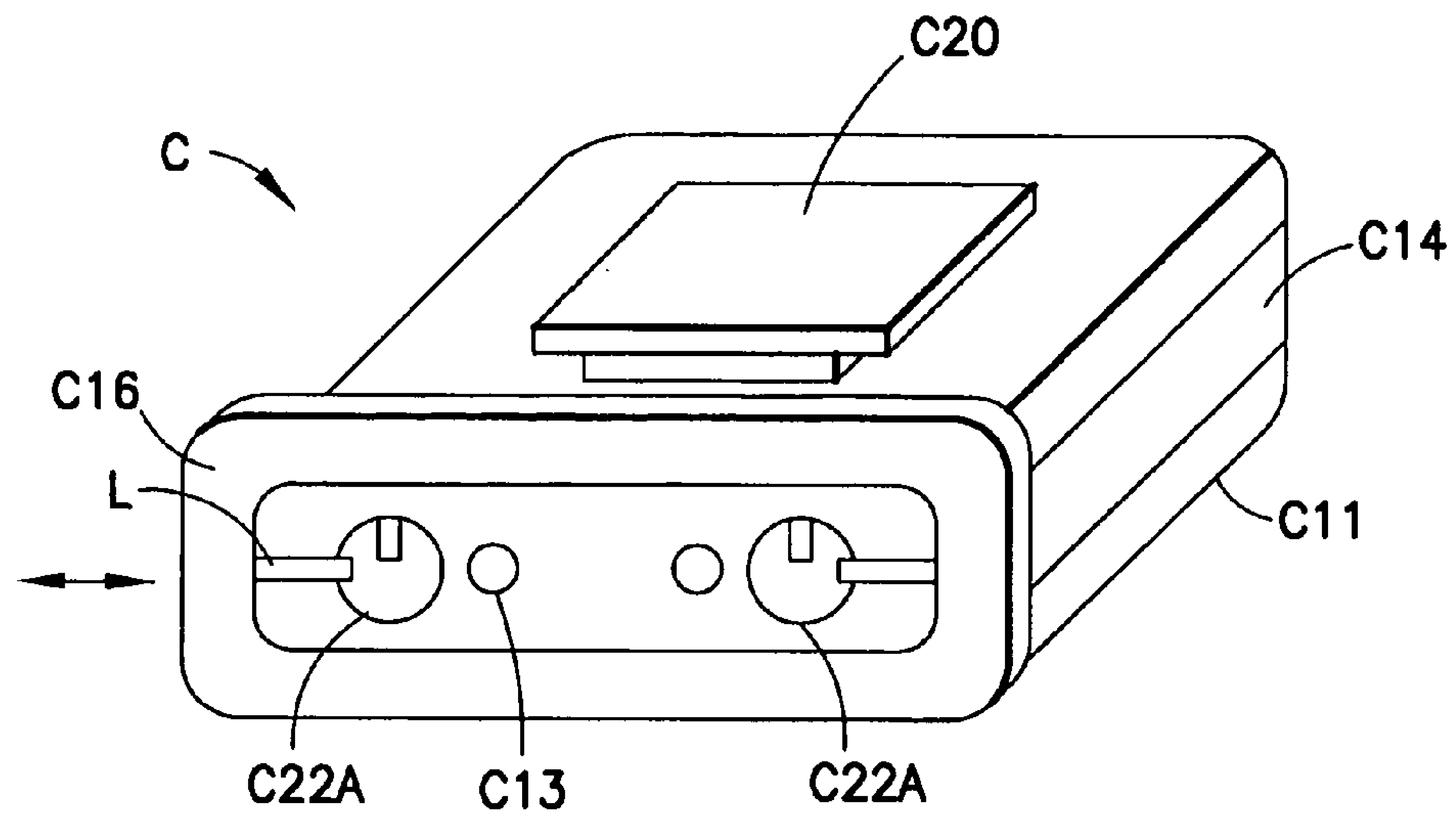


FIG.5A

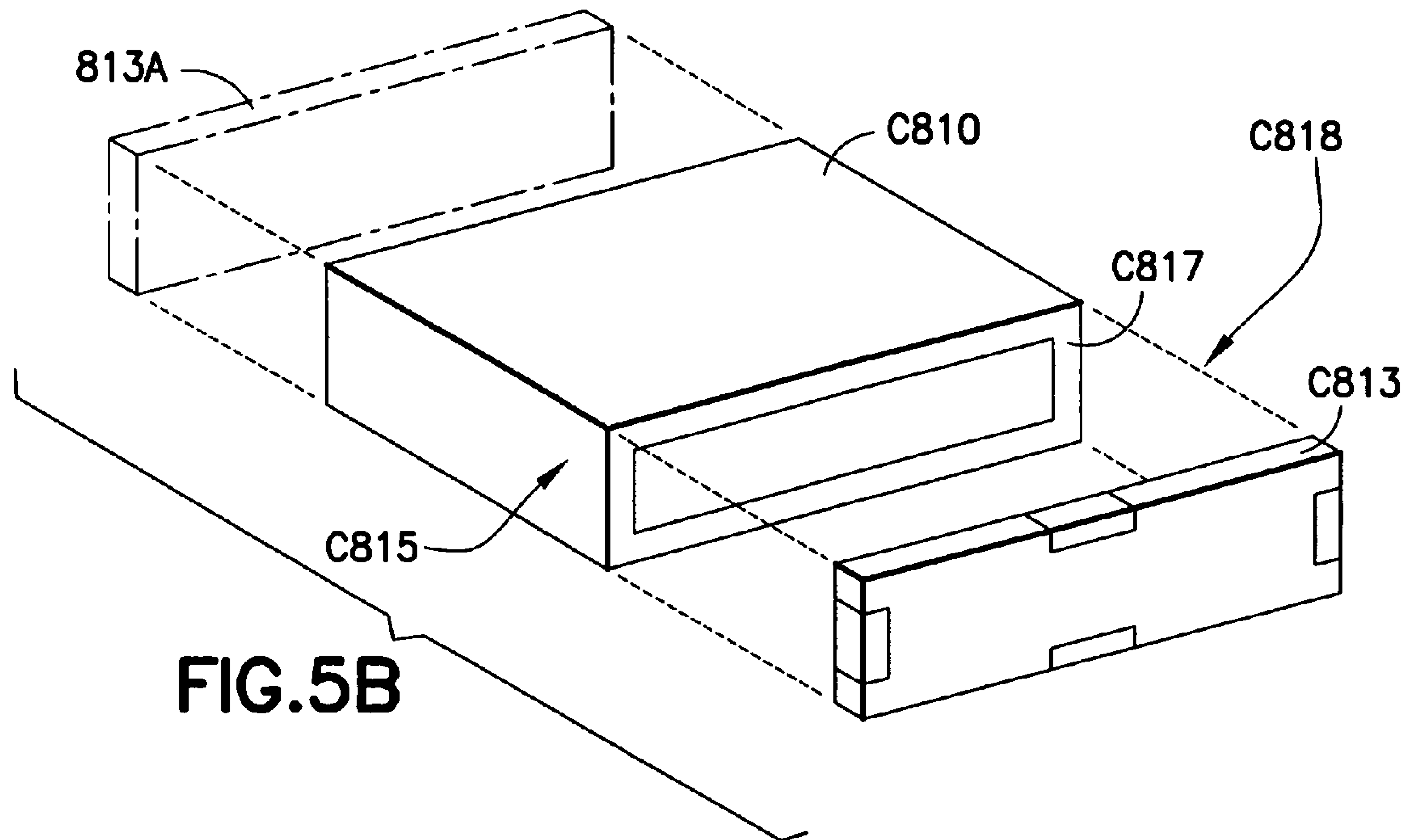


FIG.5B

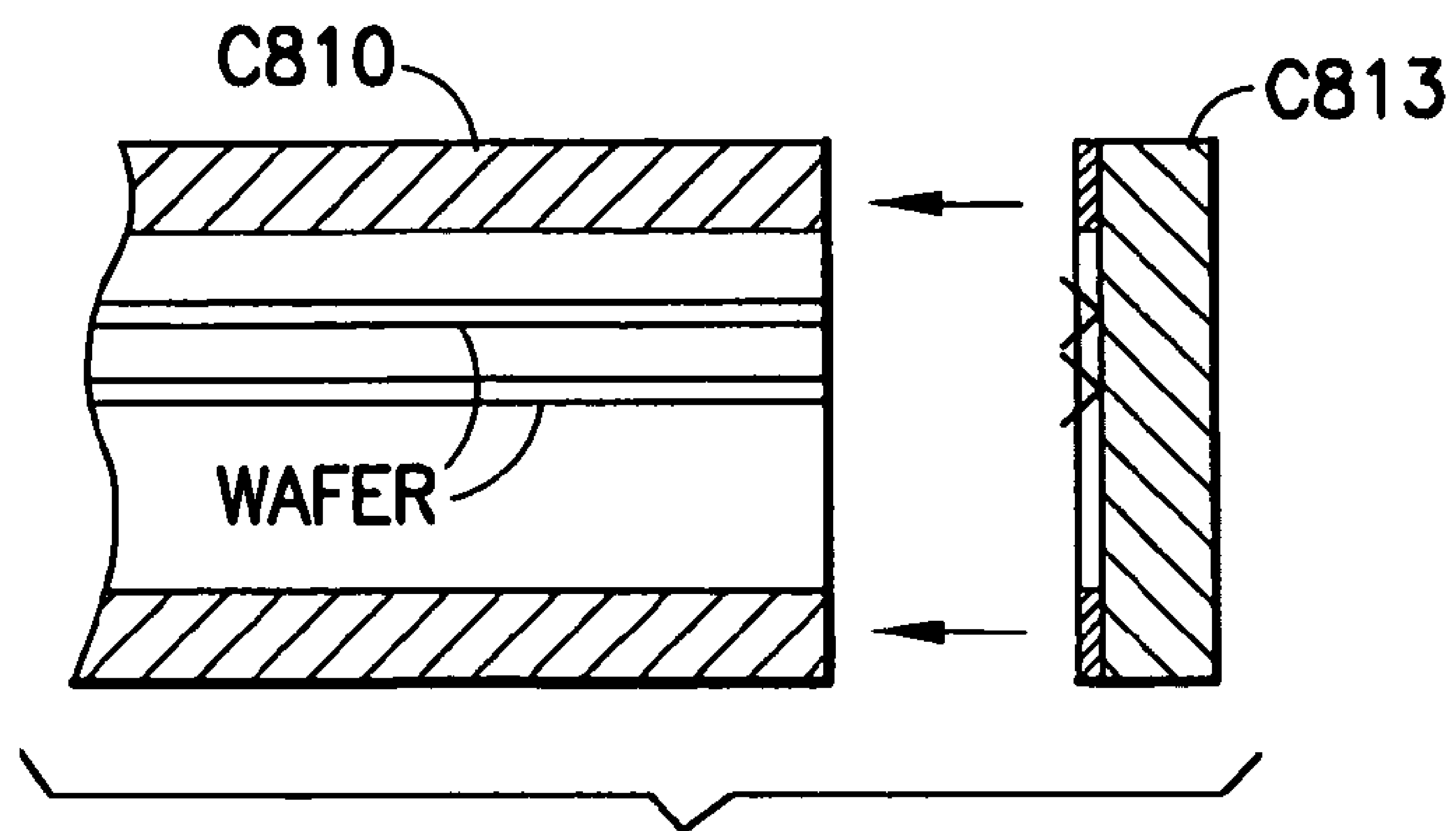


FIG.5C

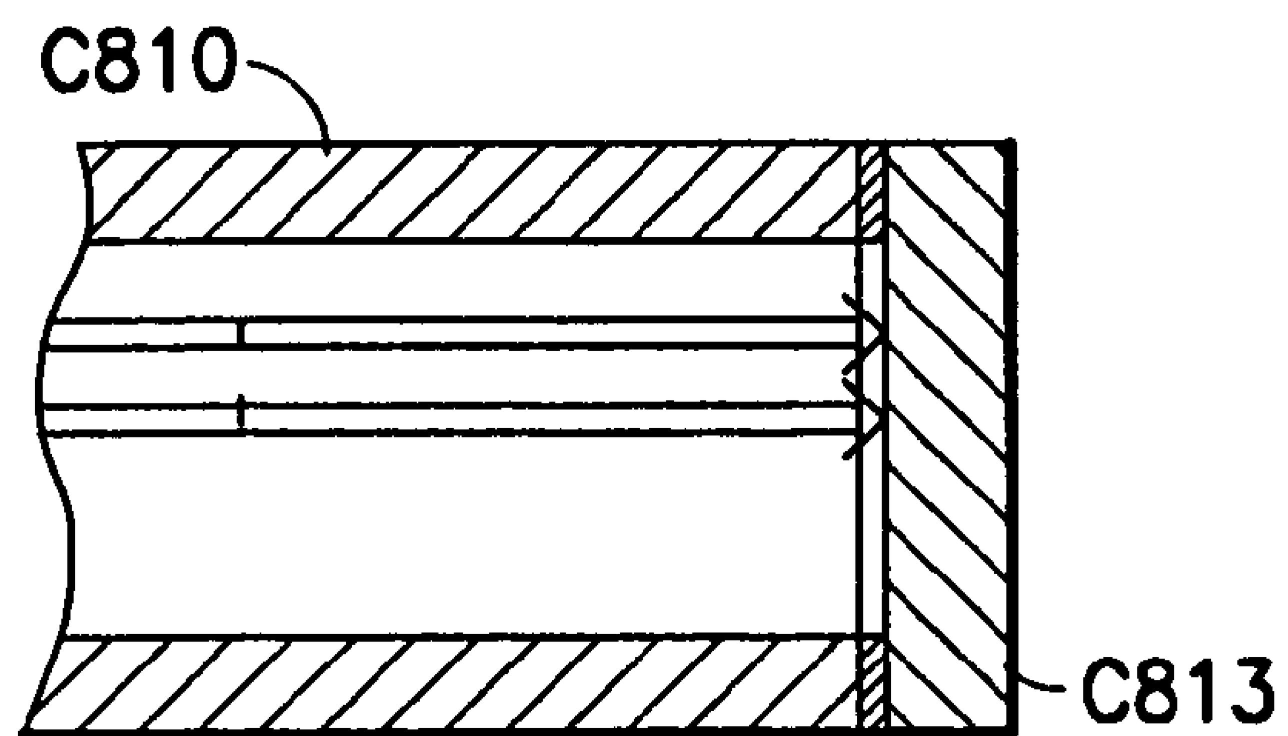


FIG.5D

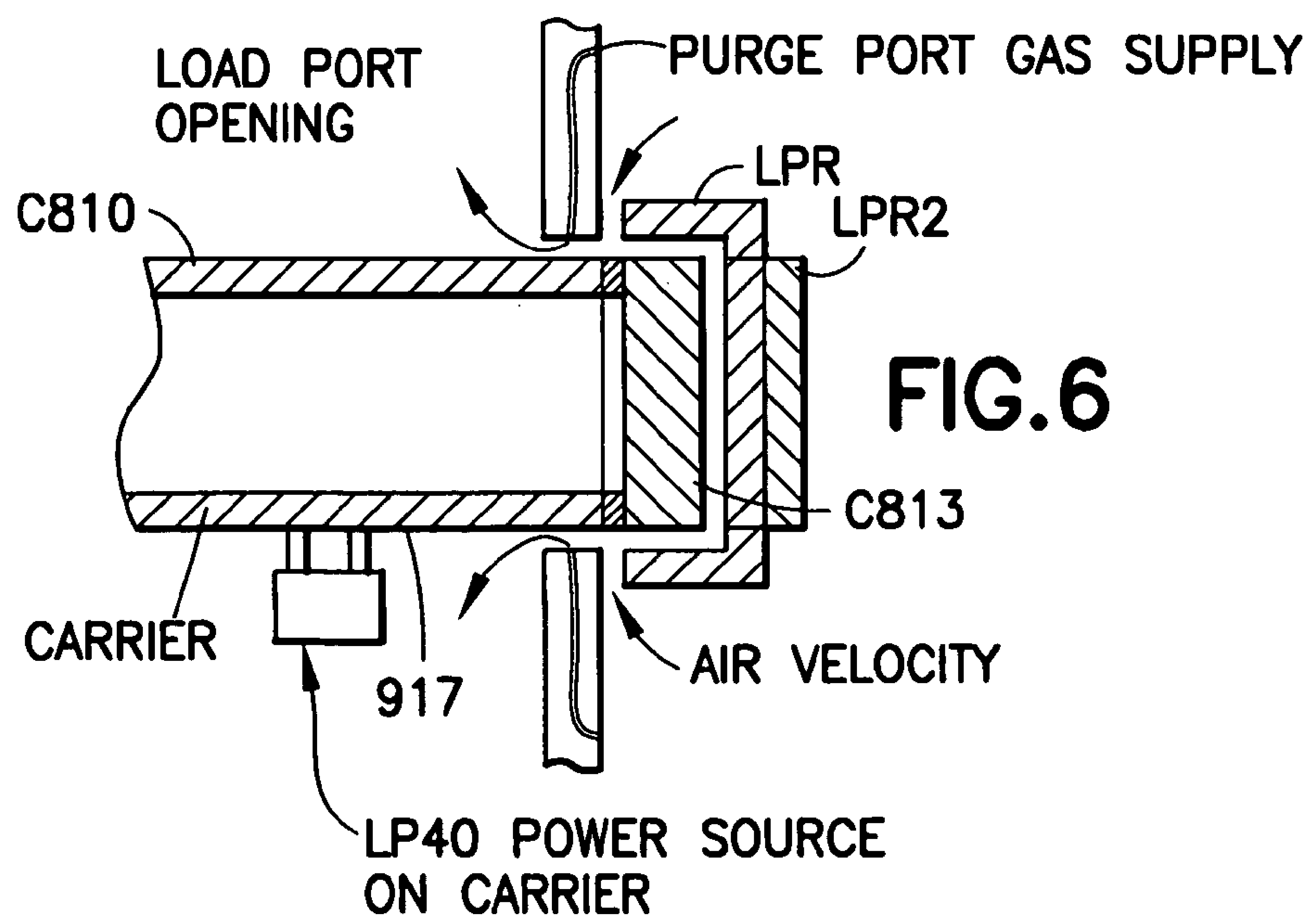


FIG.6

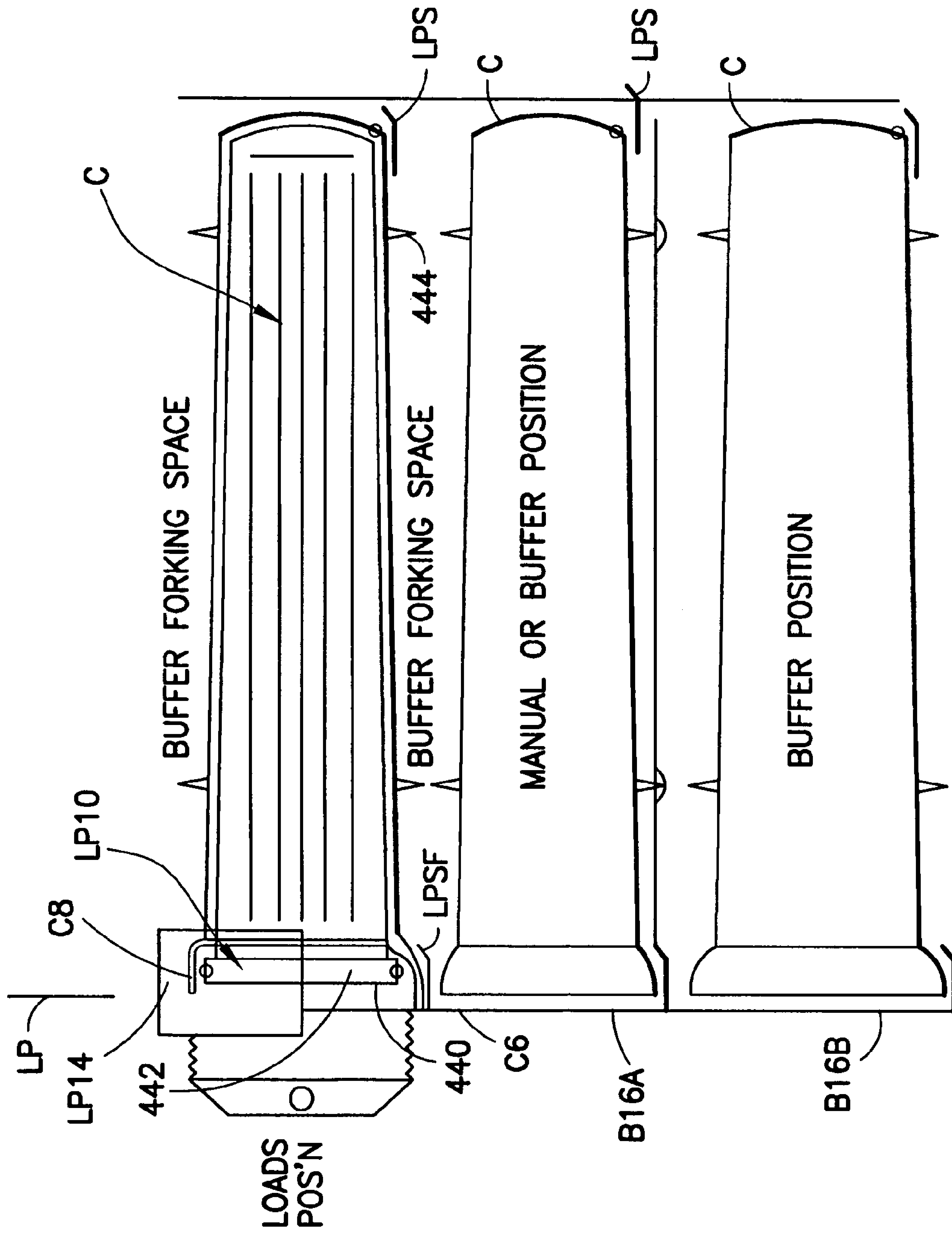


FIG.8A

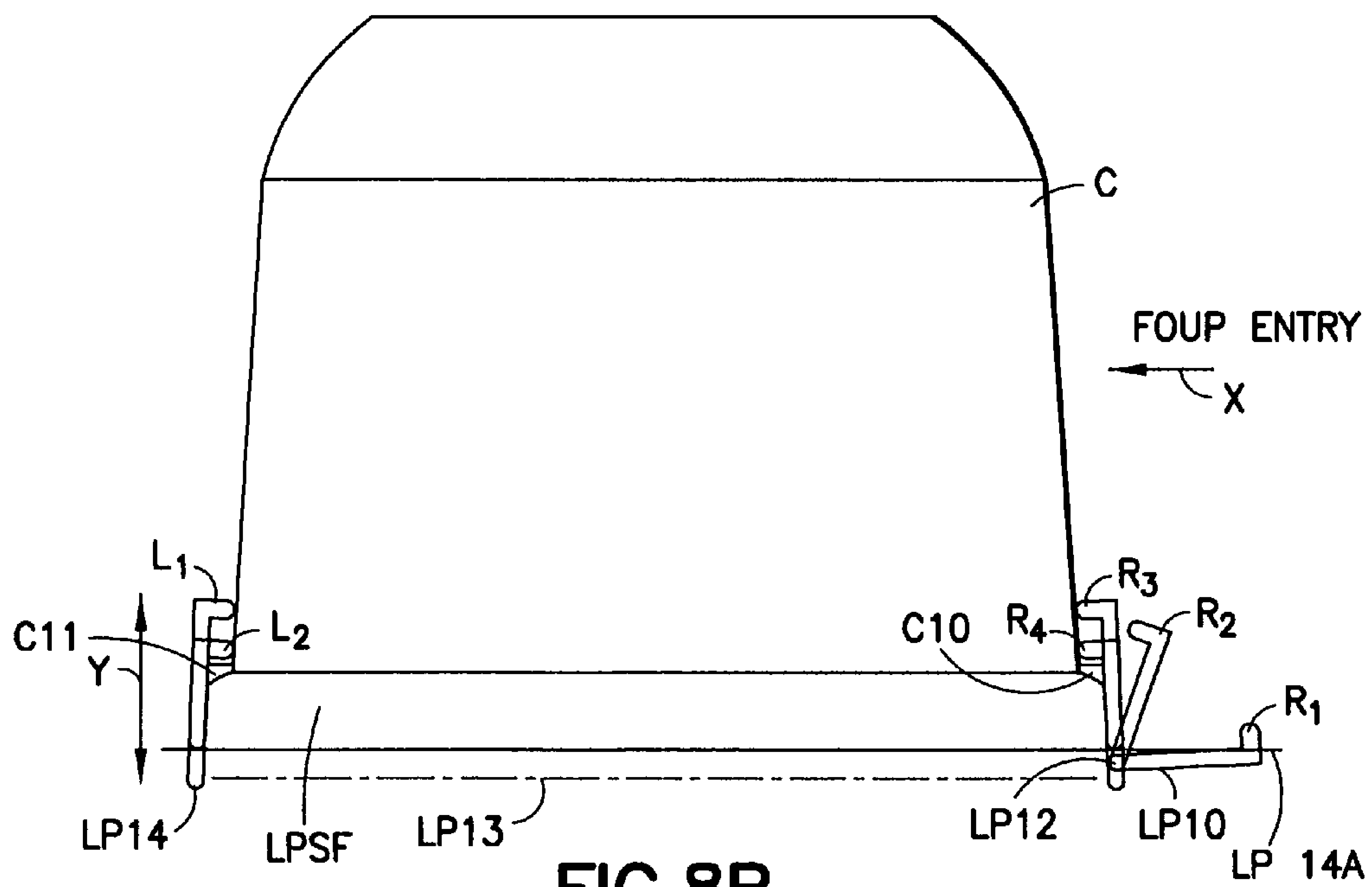


FIG.8B

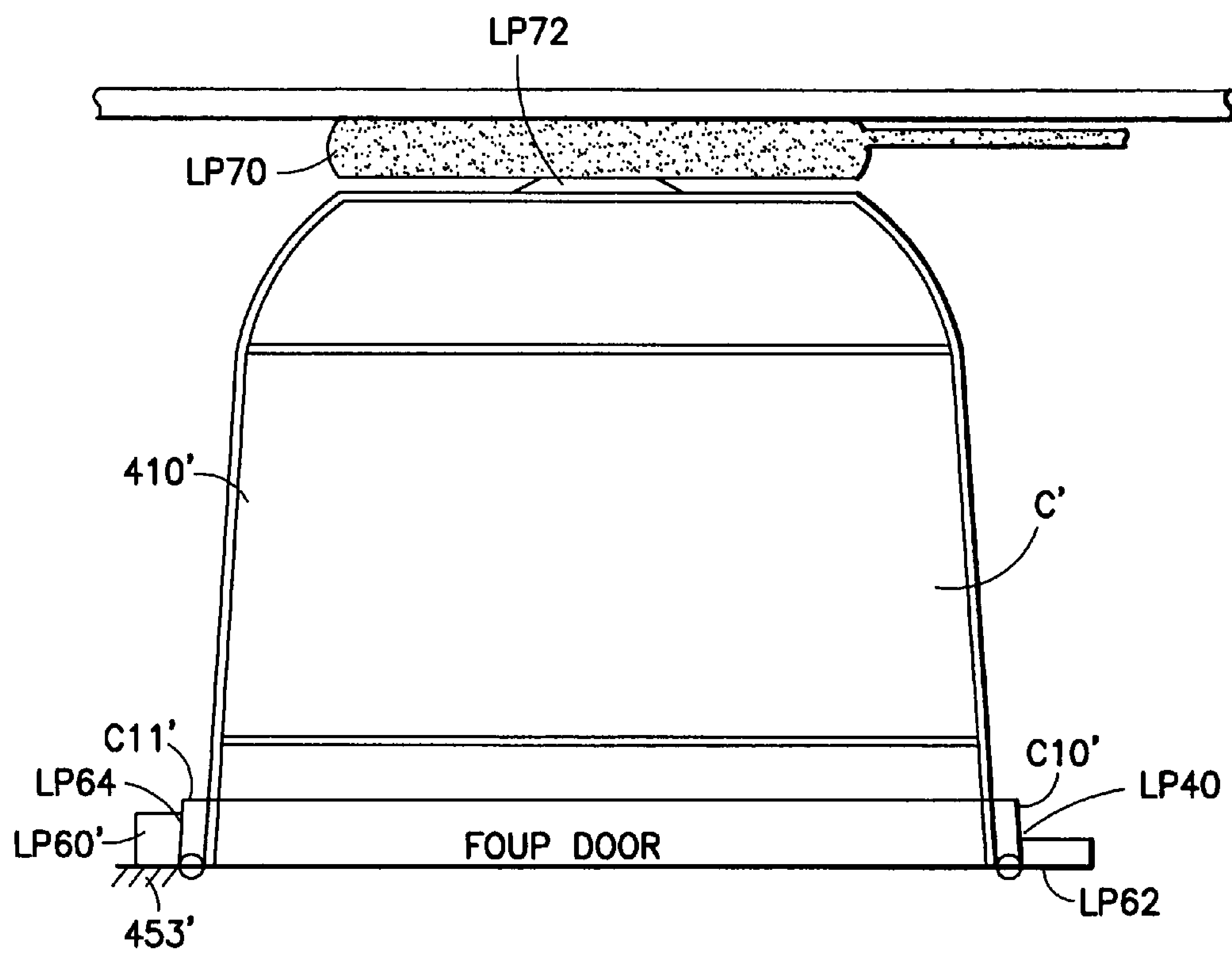


FIG.9

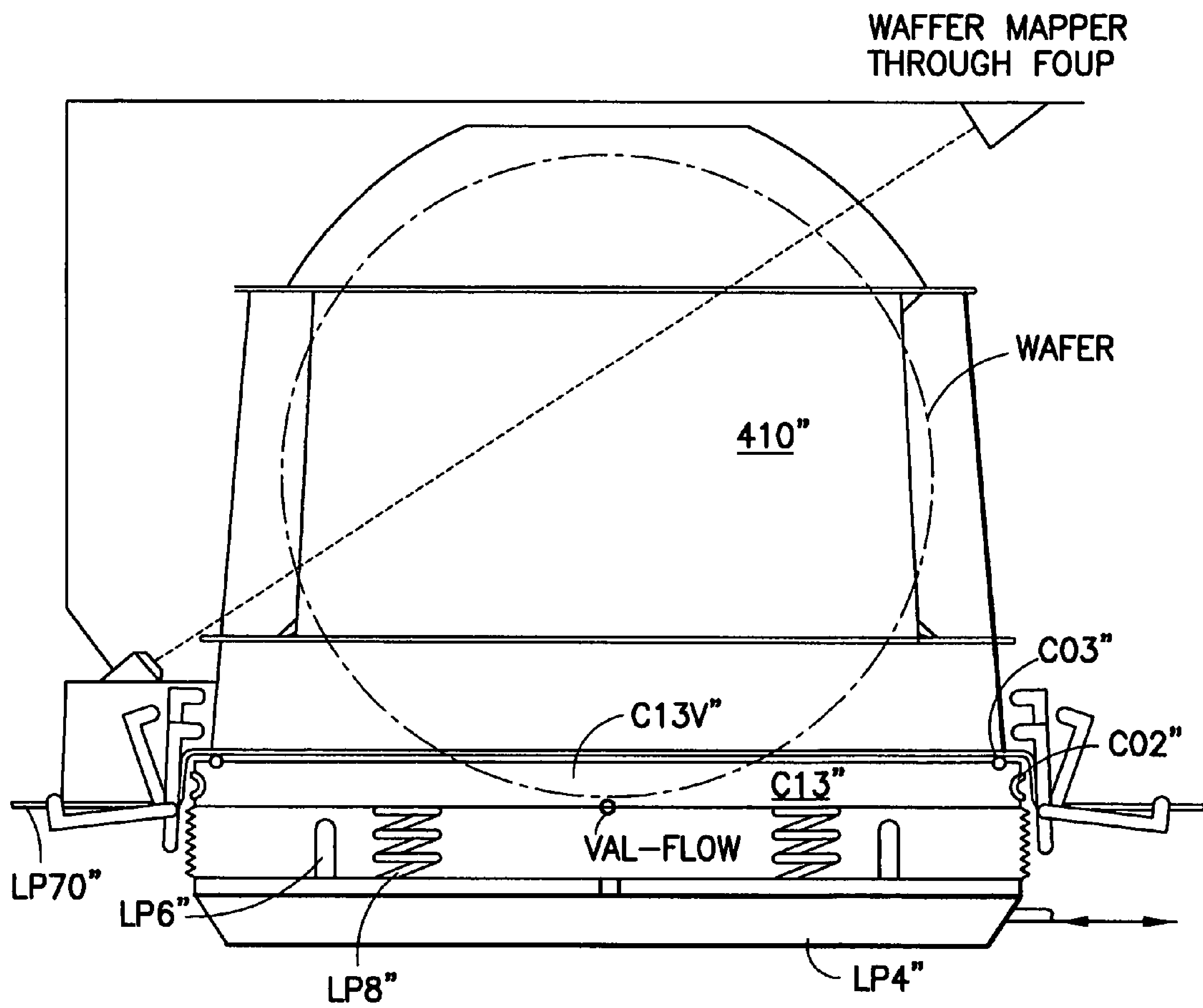


FIG.10

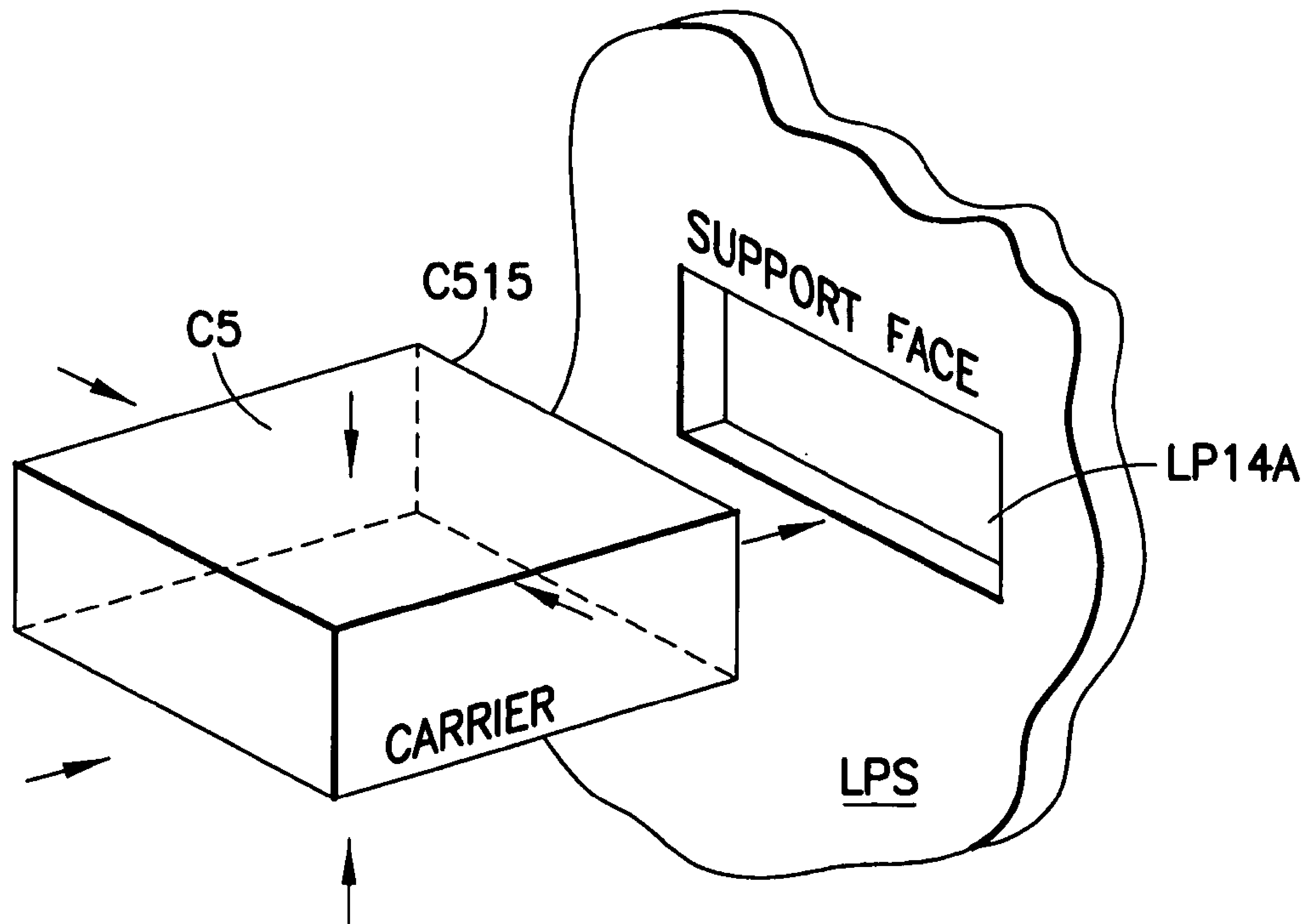


FIG.11

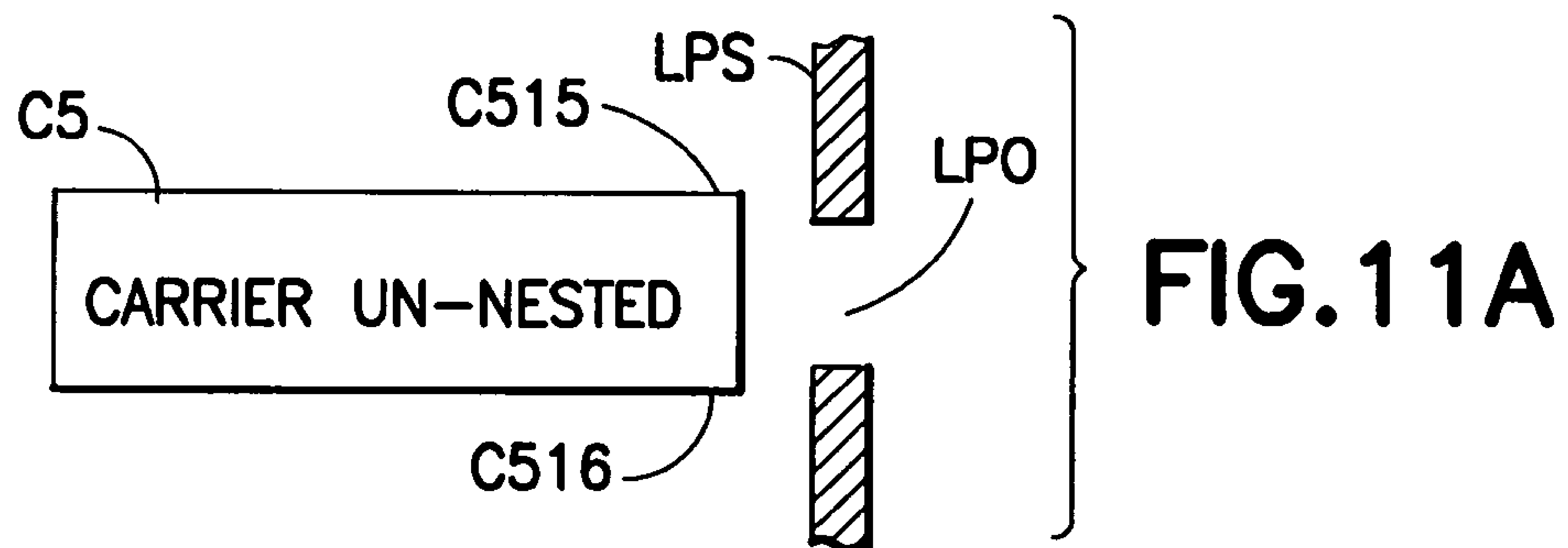


FIG.11A

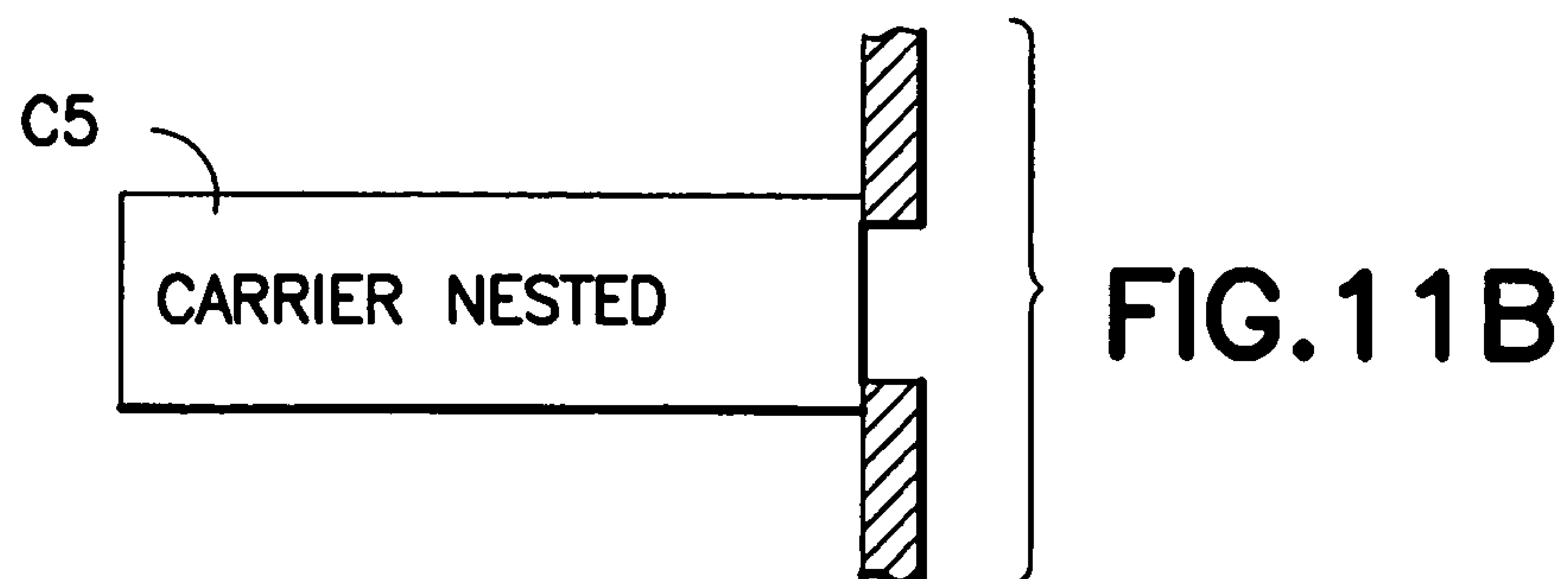


FIG.11B

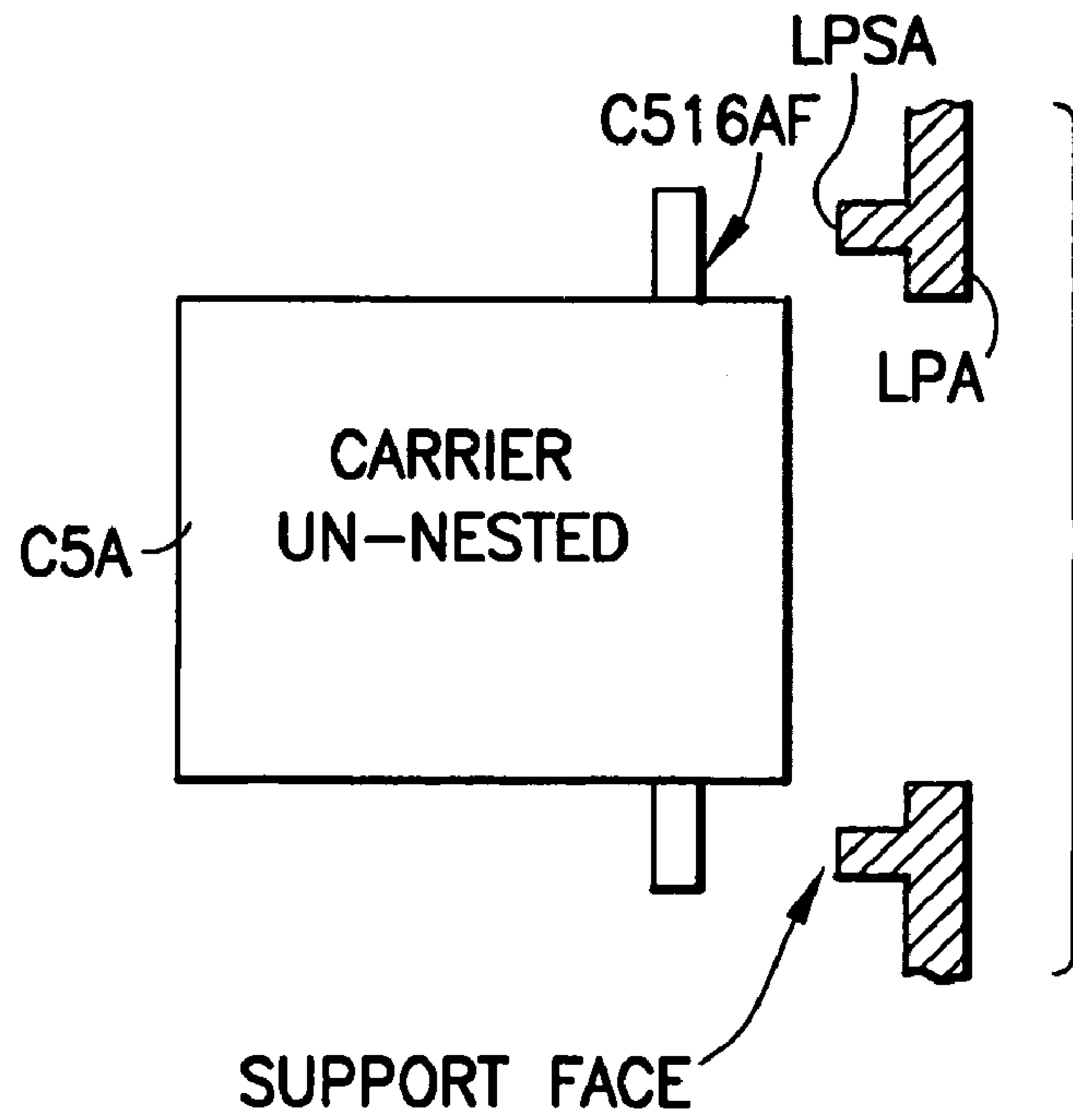


FIG.12A

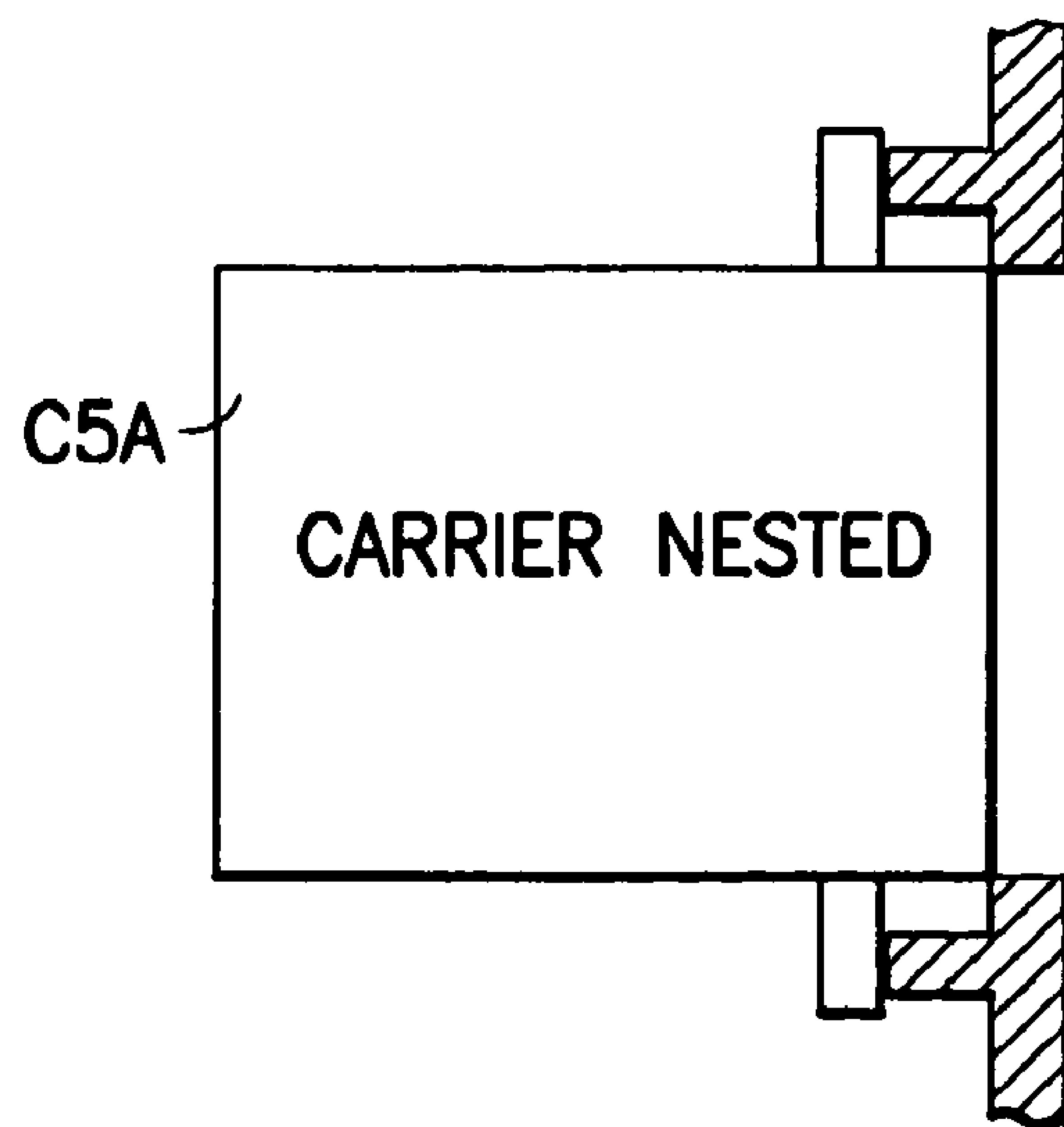


FIG.12B

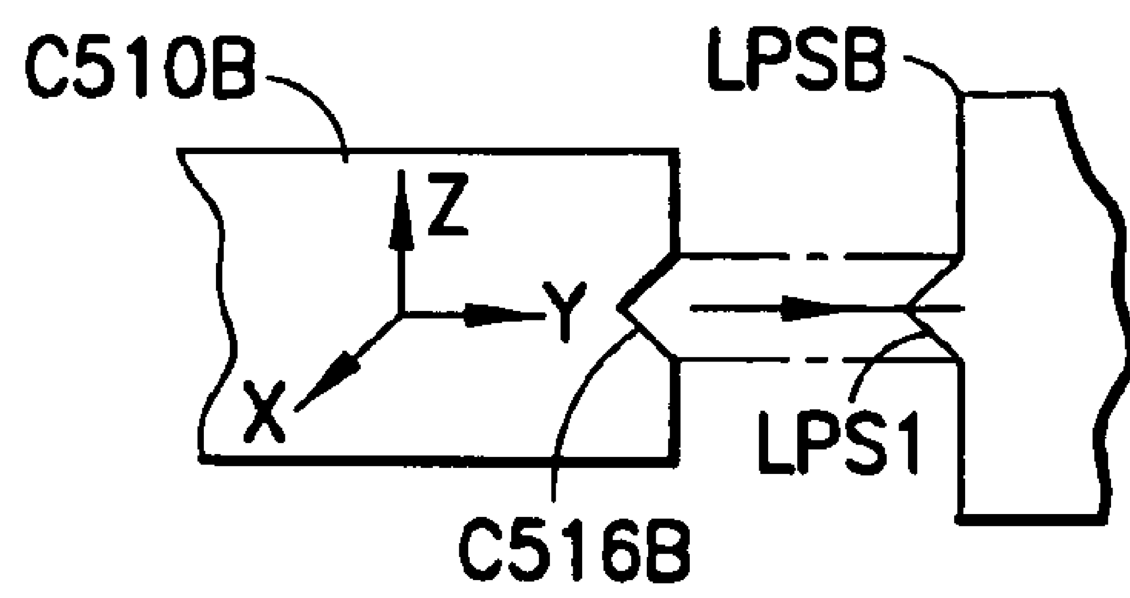


FIG.13A

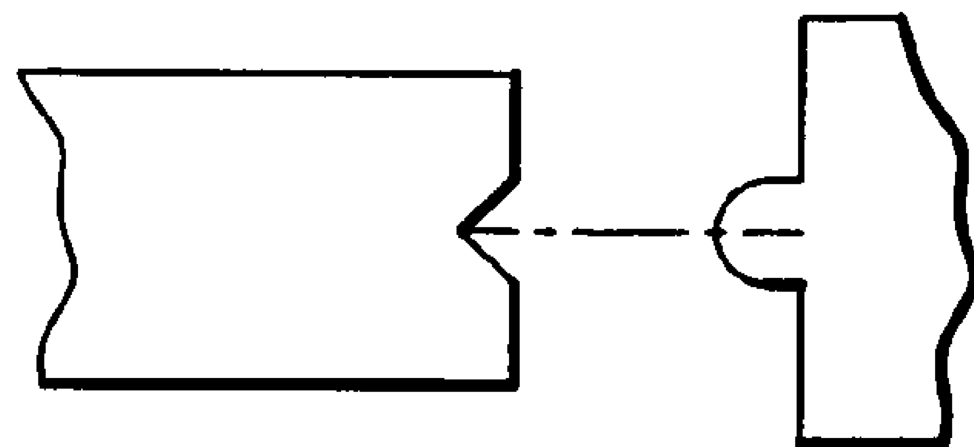


FIG.13B

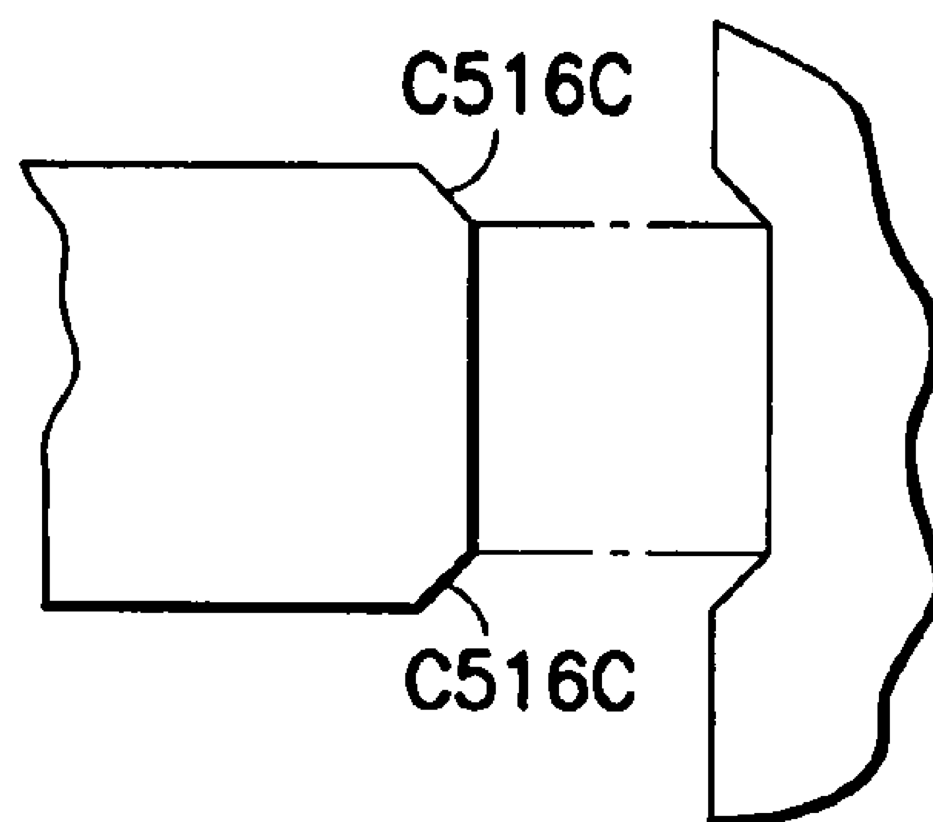


FIG.13C

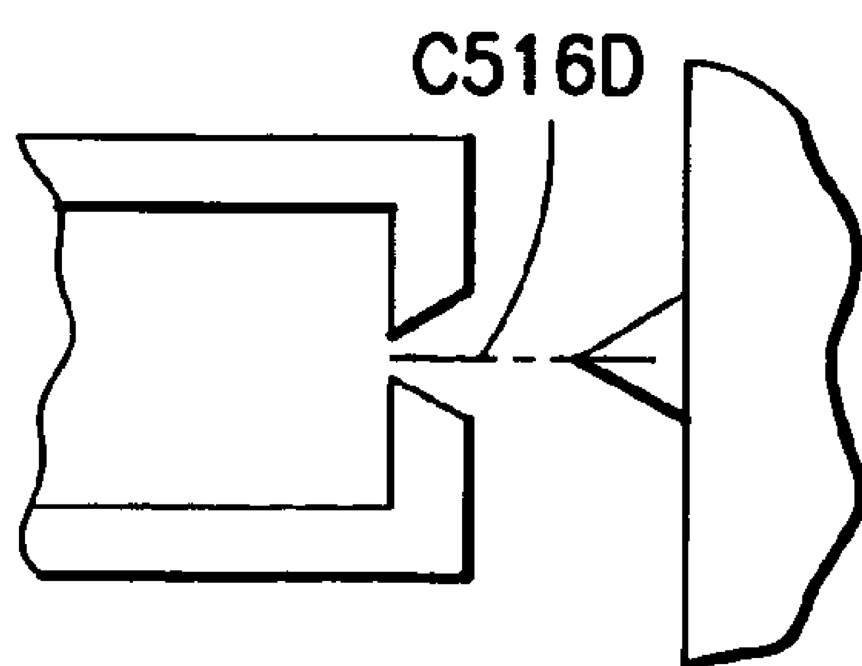


FIG.13D

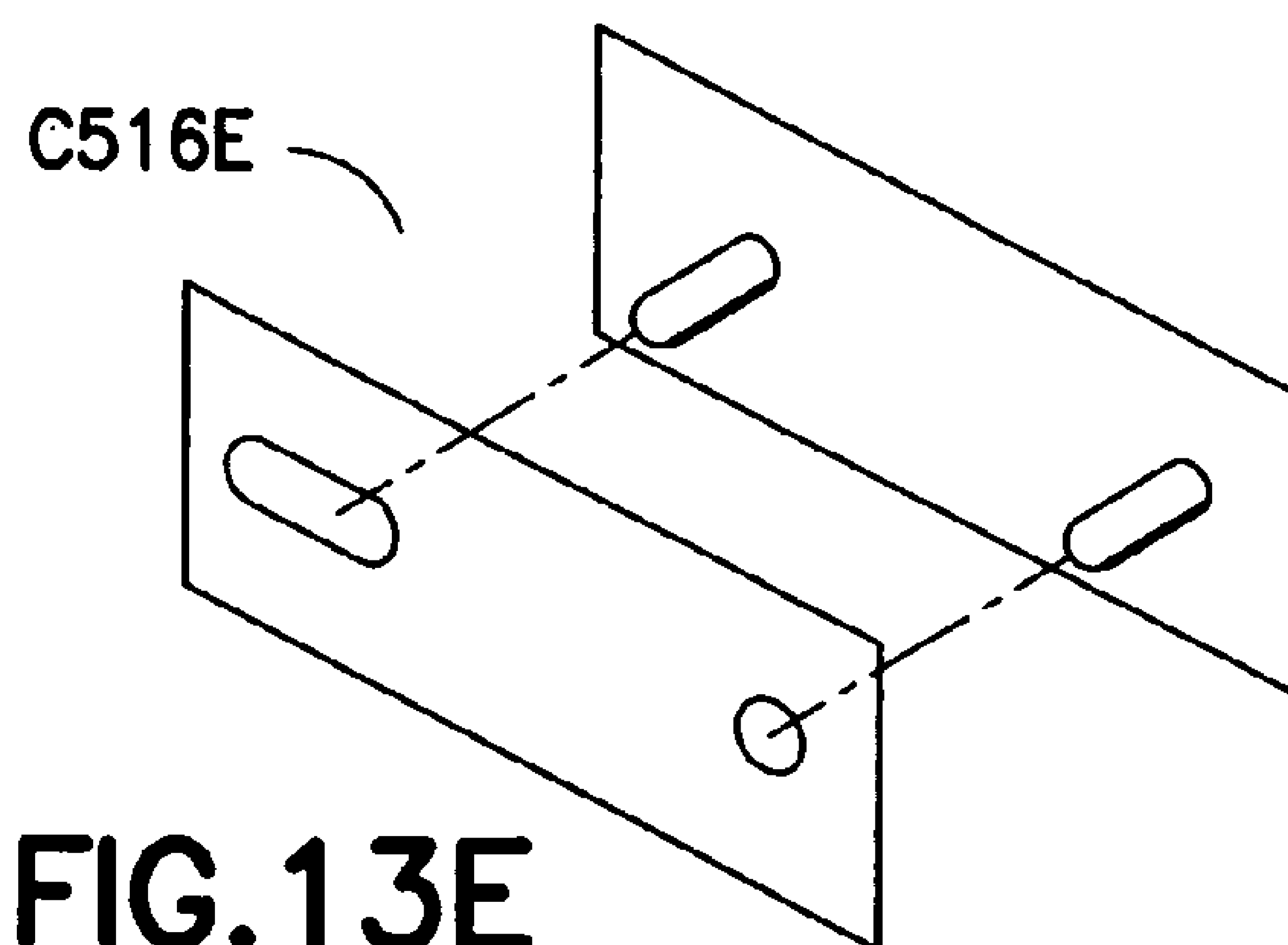


FIG.13E

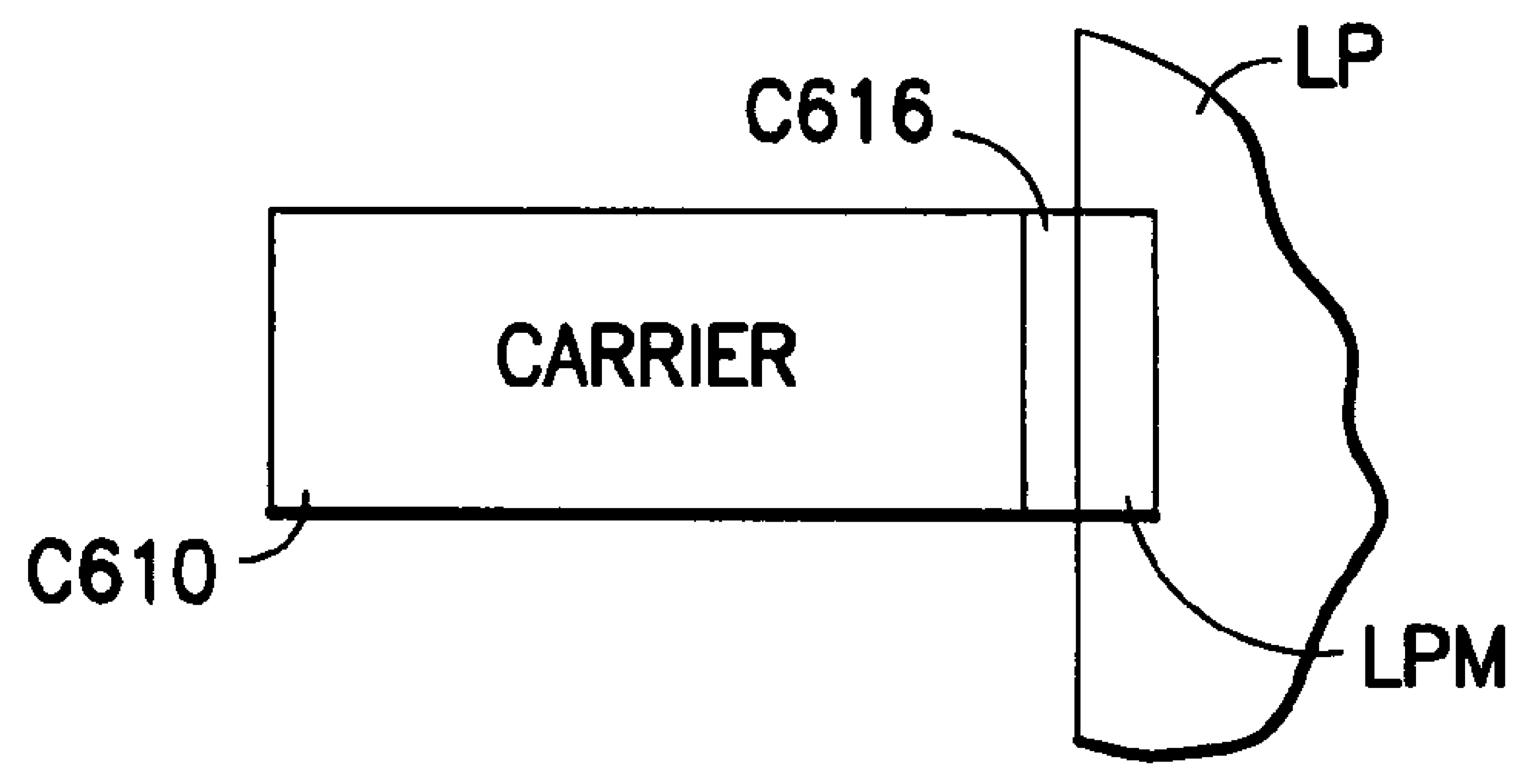


FIG.14

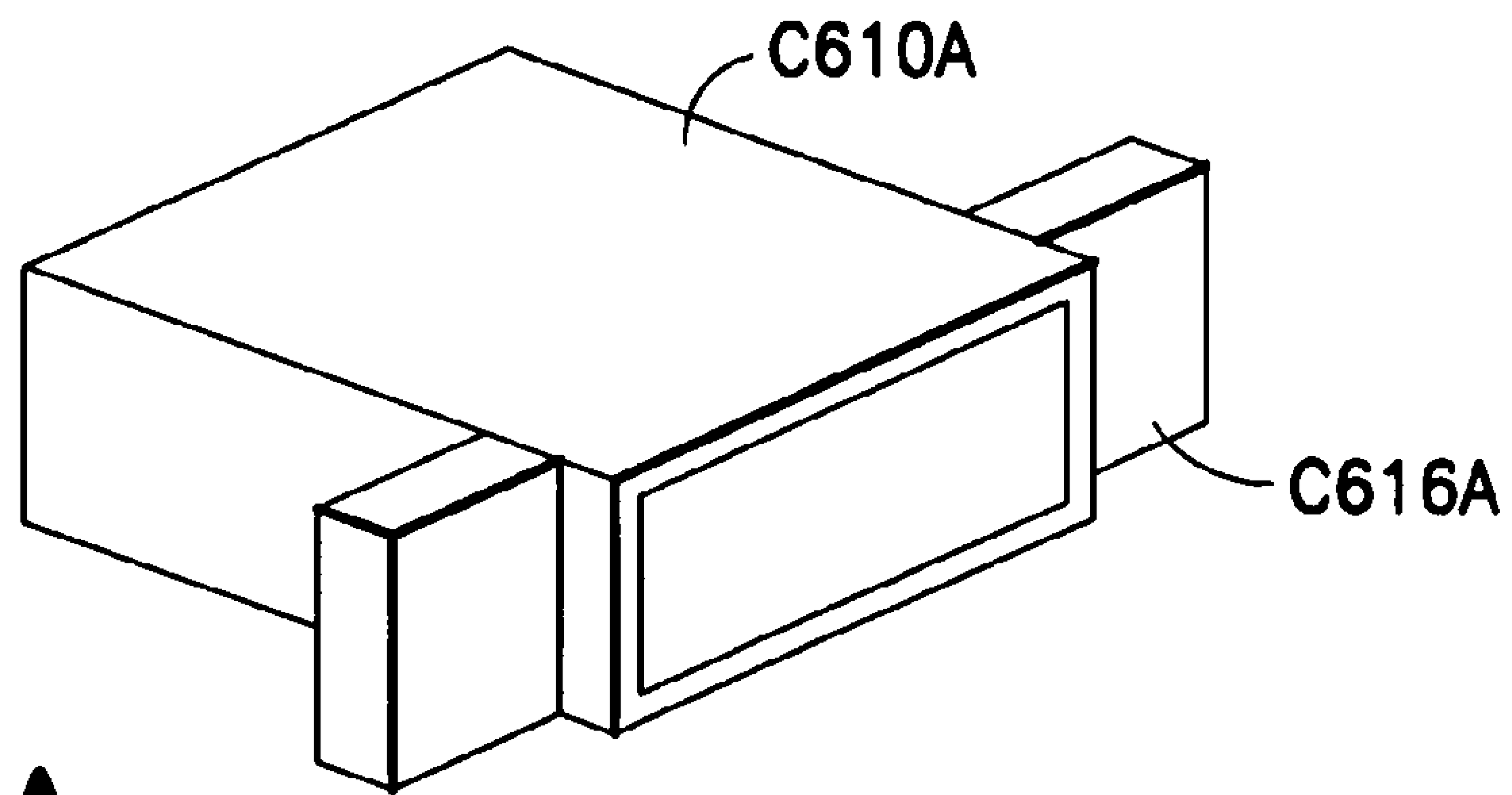


FIG.15A

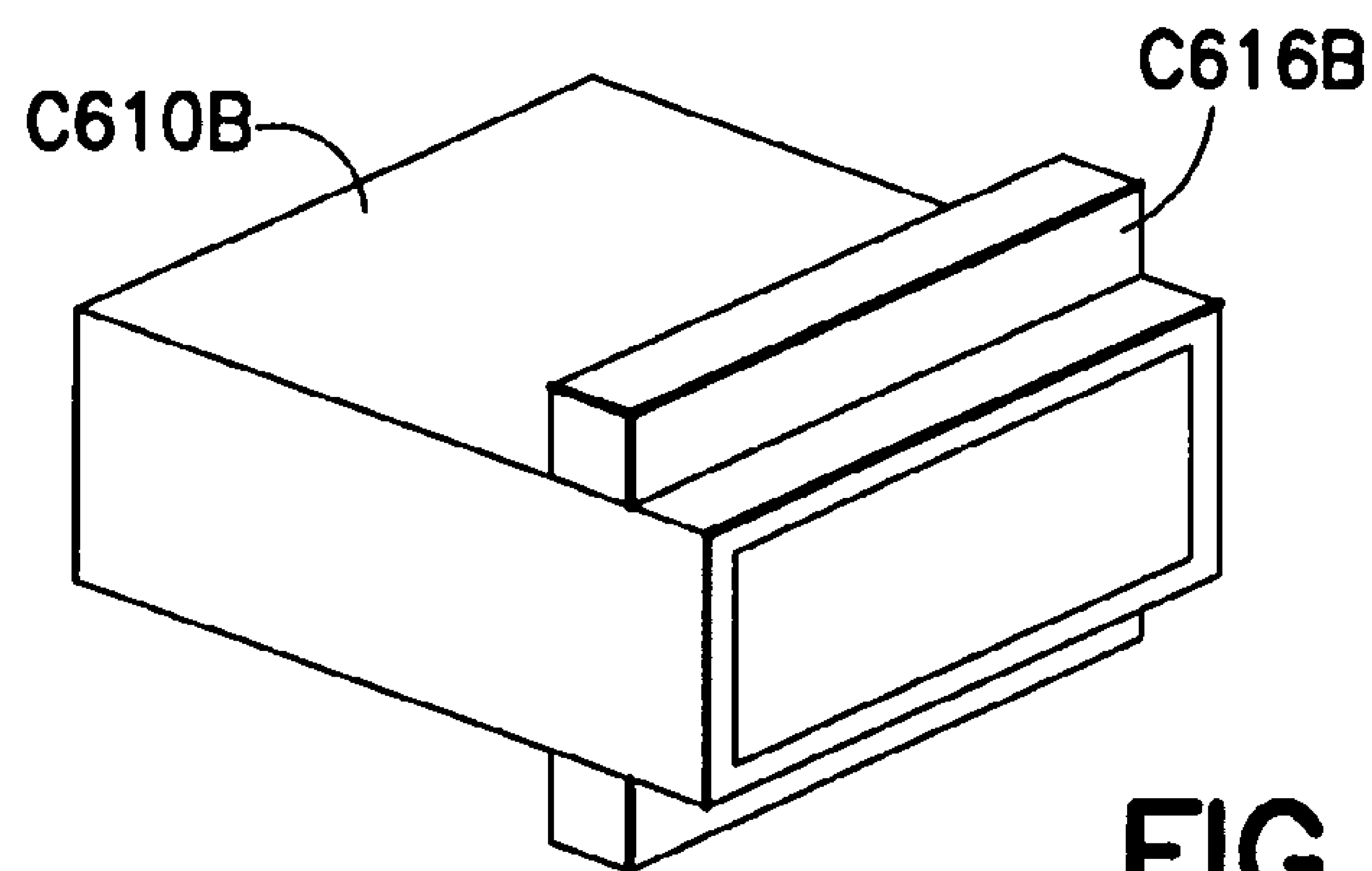


FIG.15B

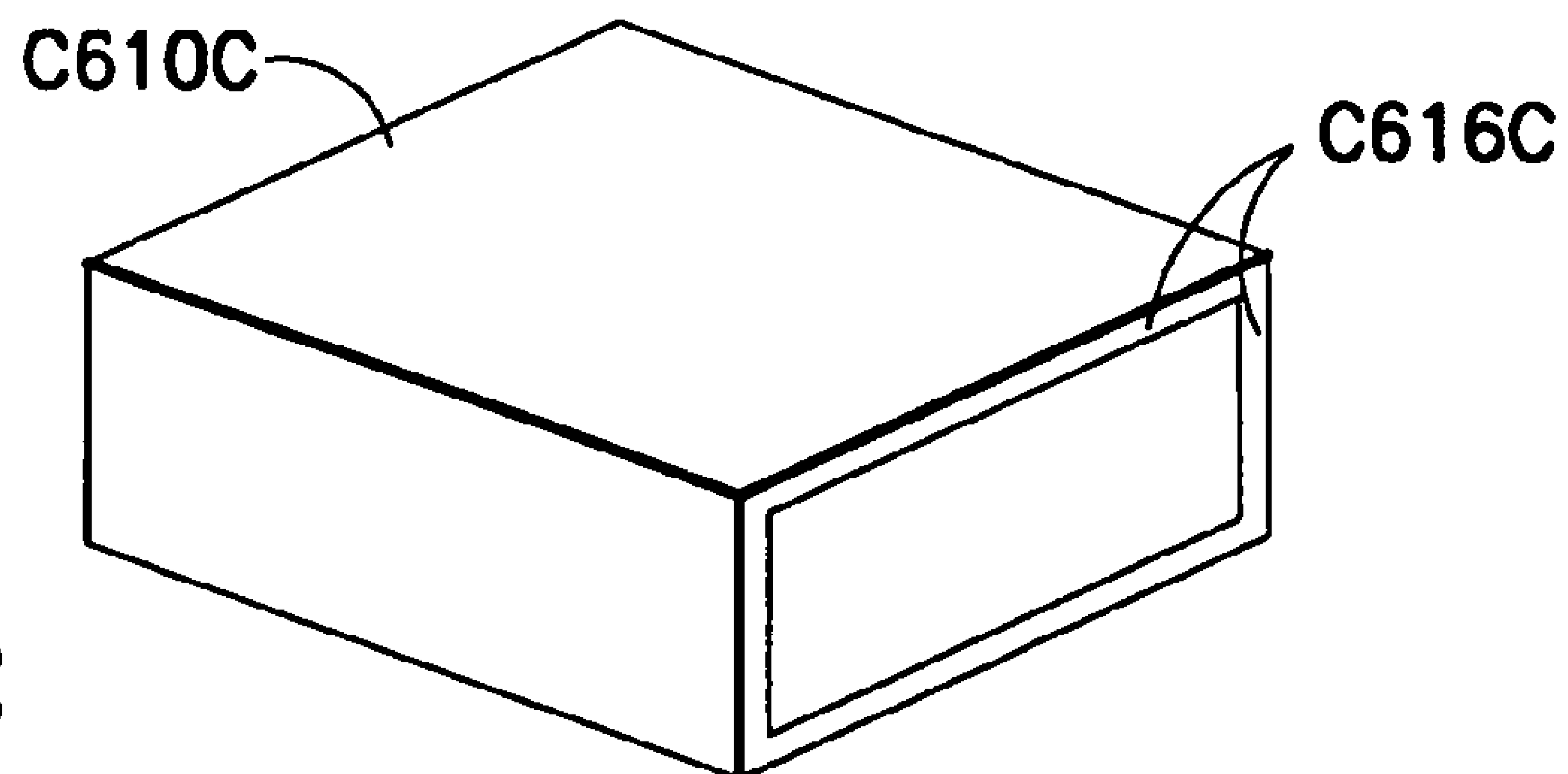


FIG.15C

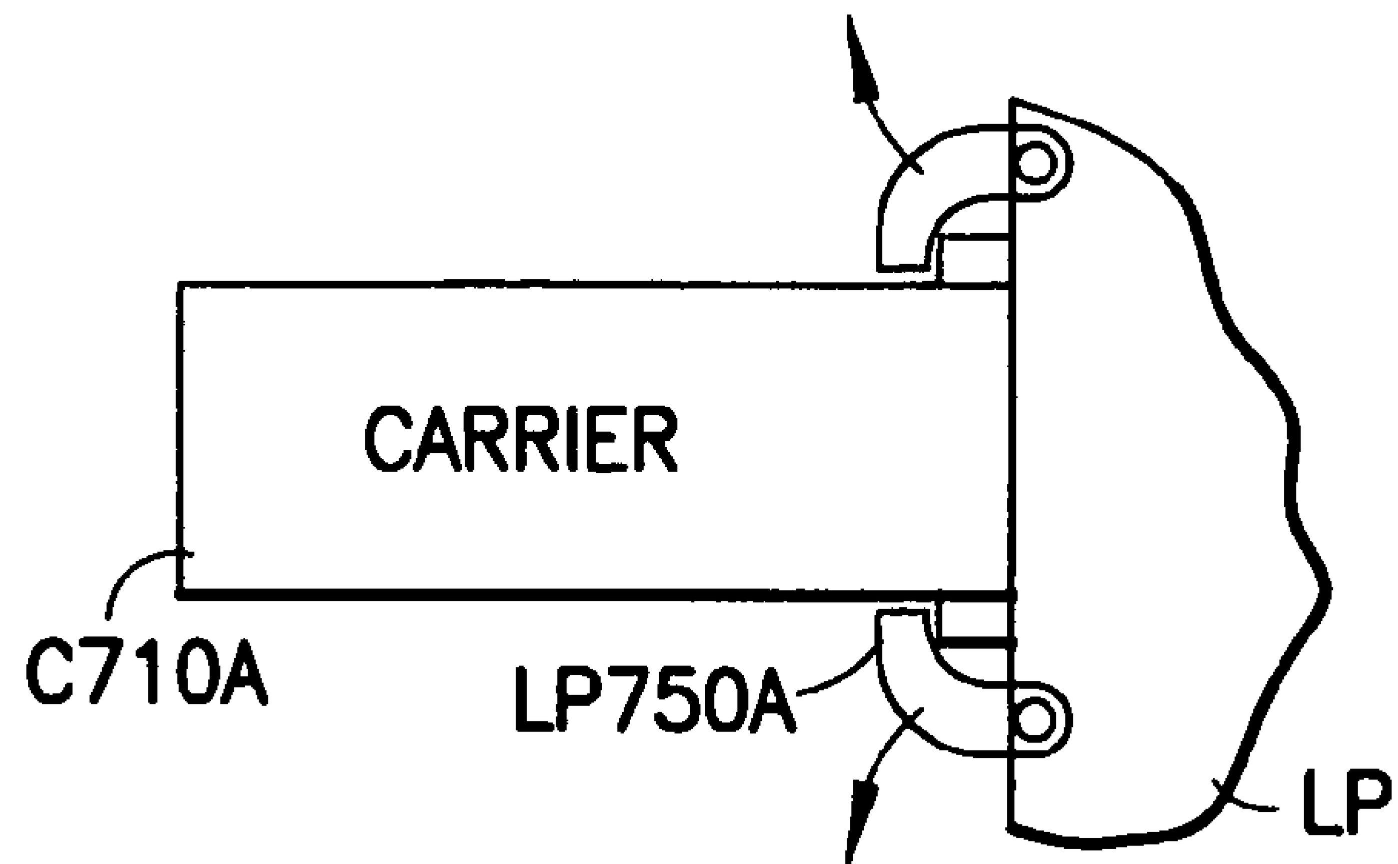


FIG. 16A

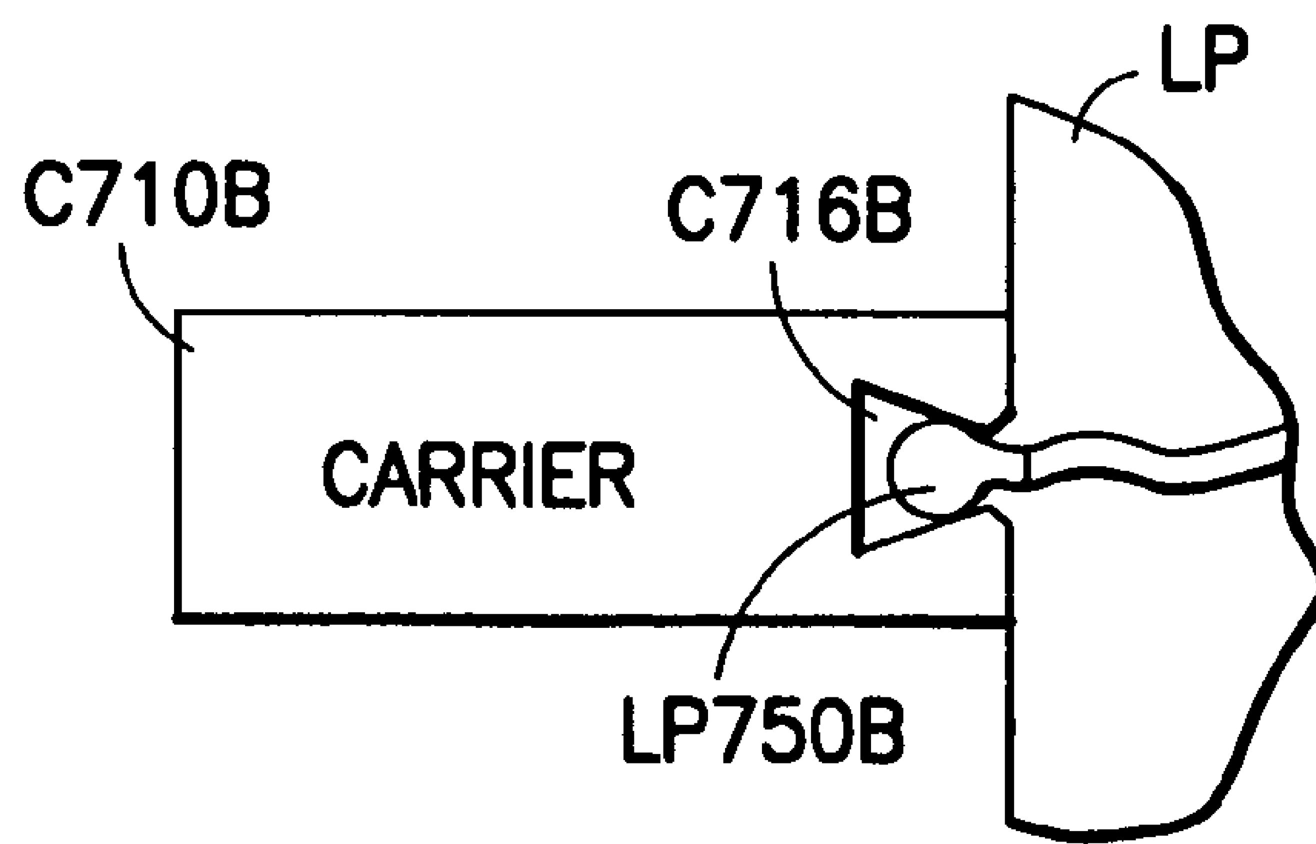


FIG. 16B

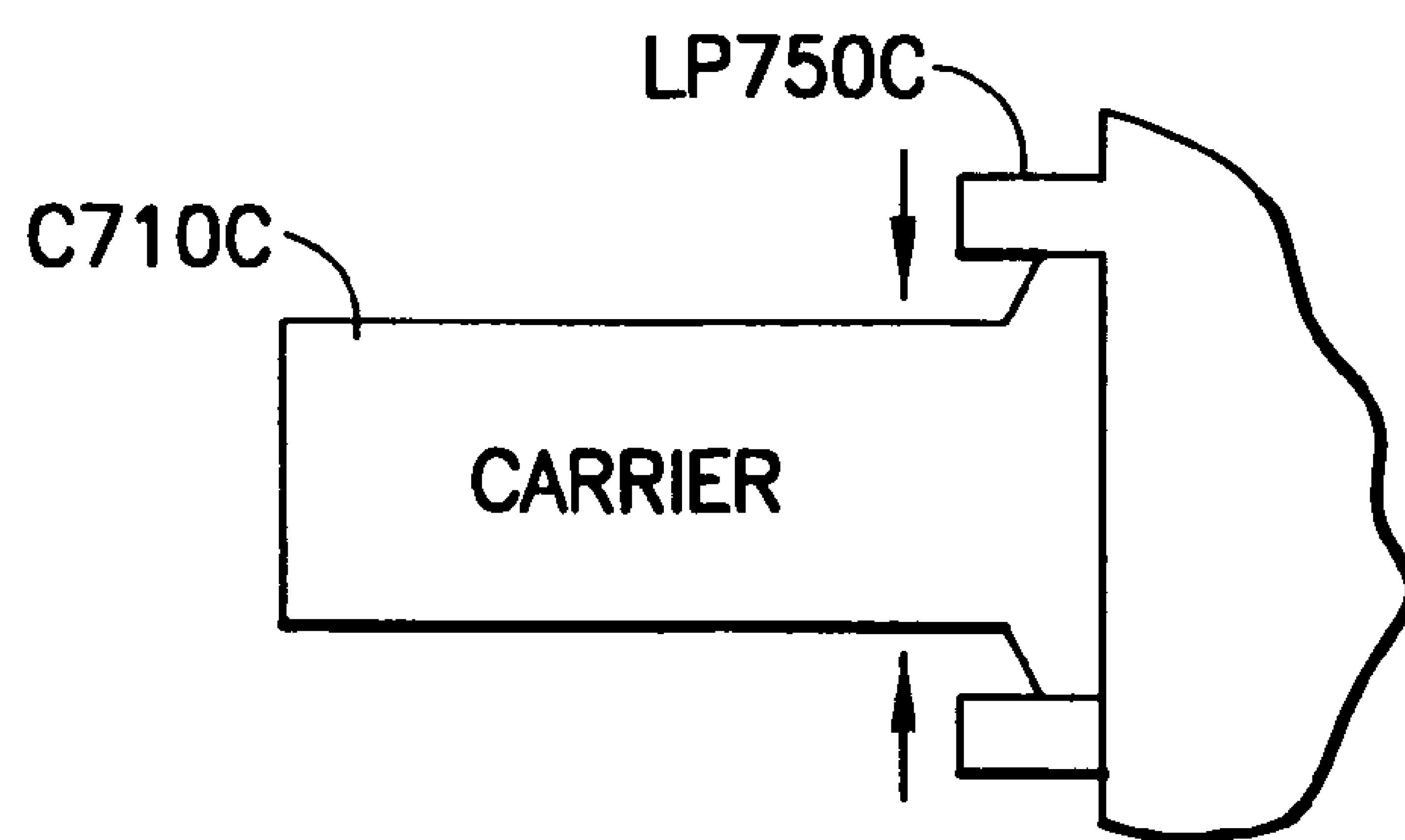


FIG. 16C

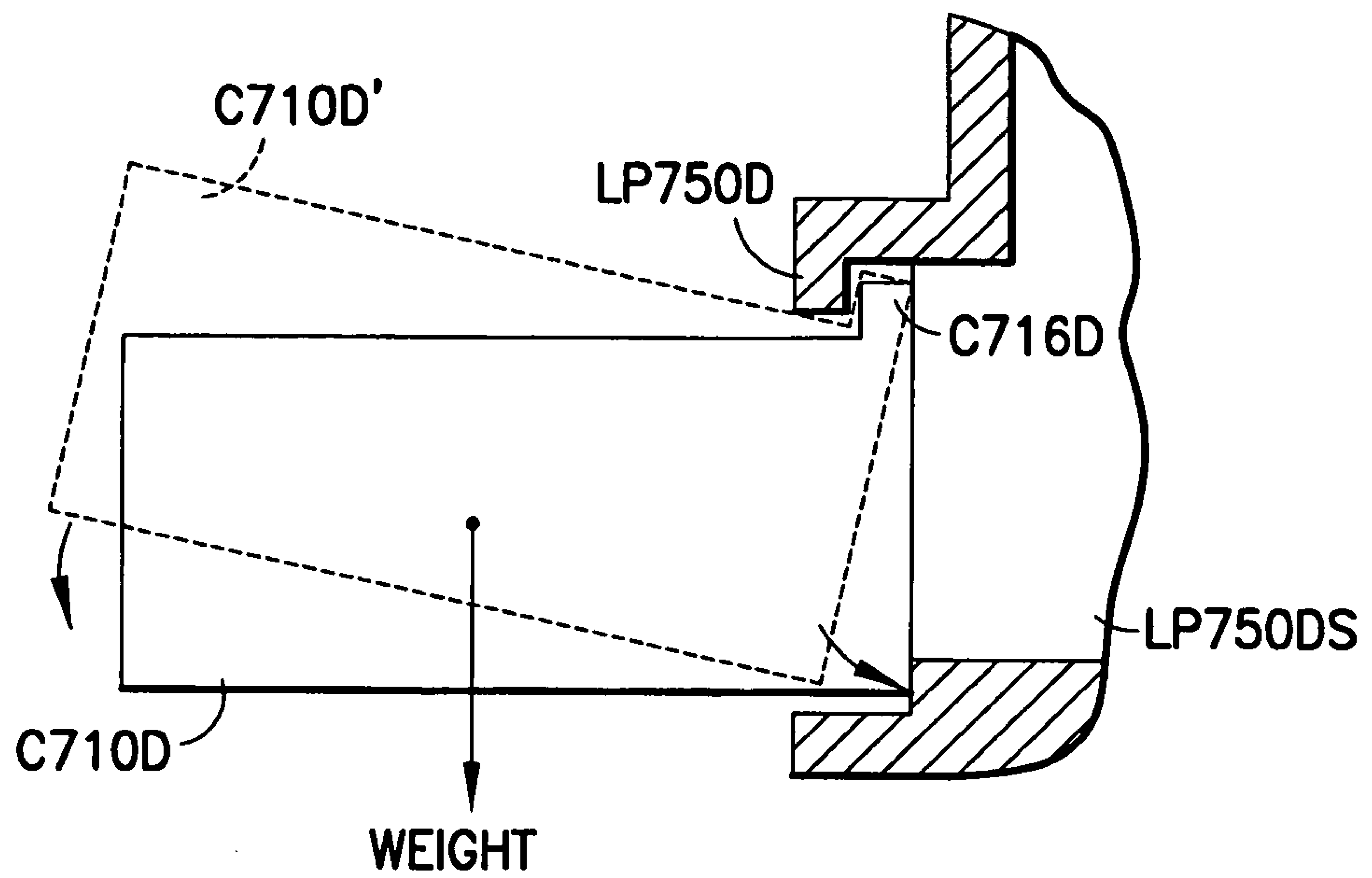


FIG. 16D

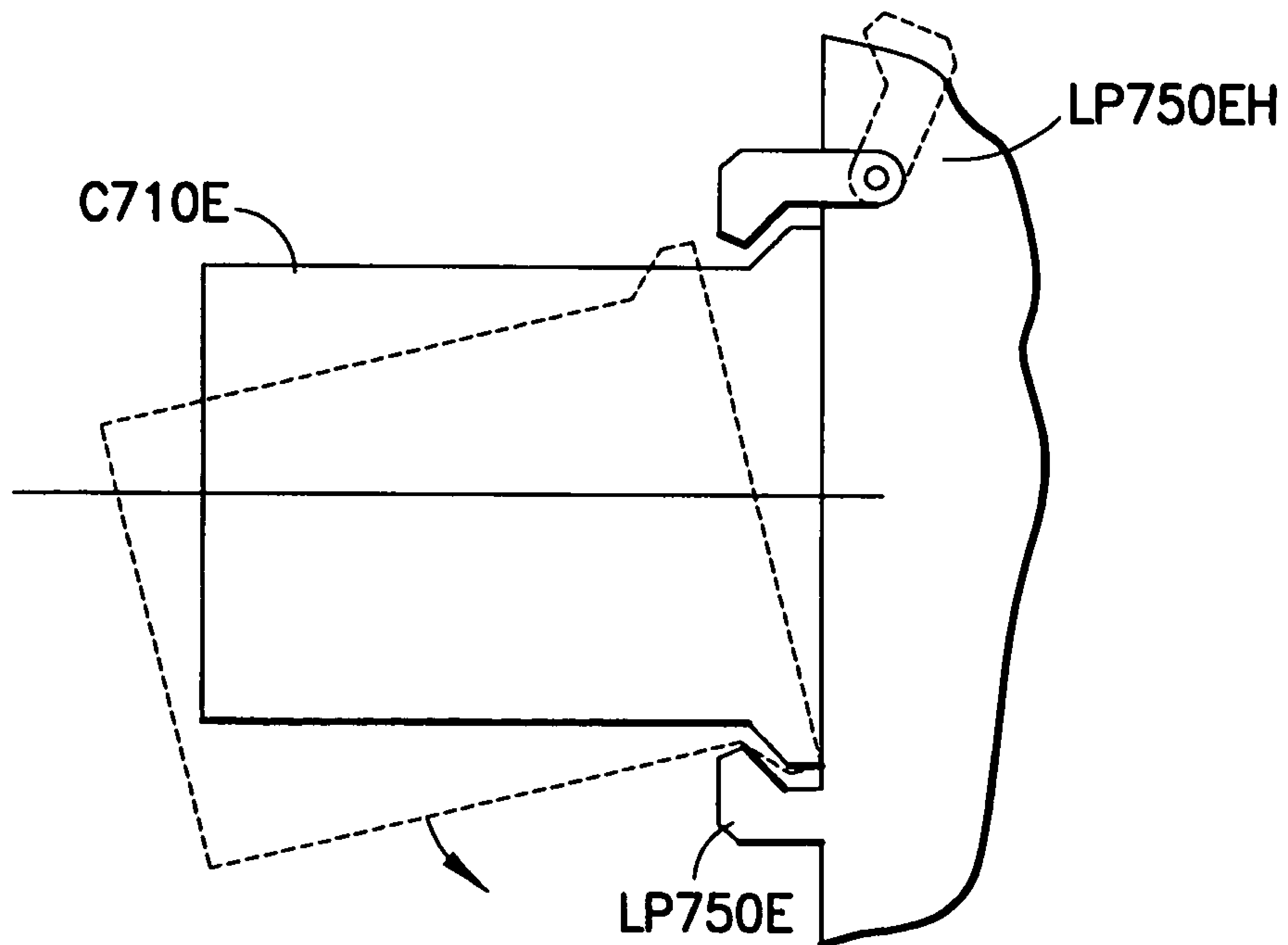


FIG. 16E

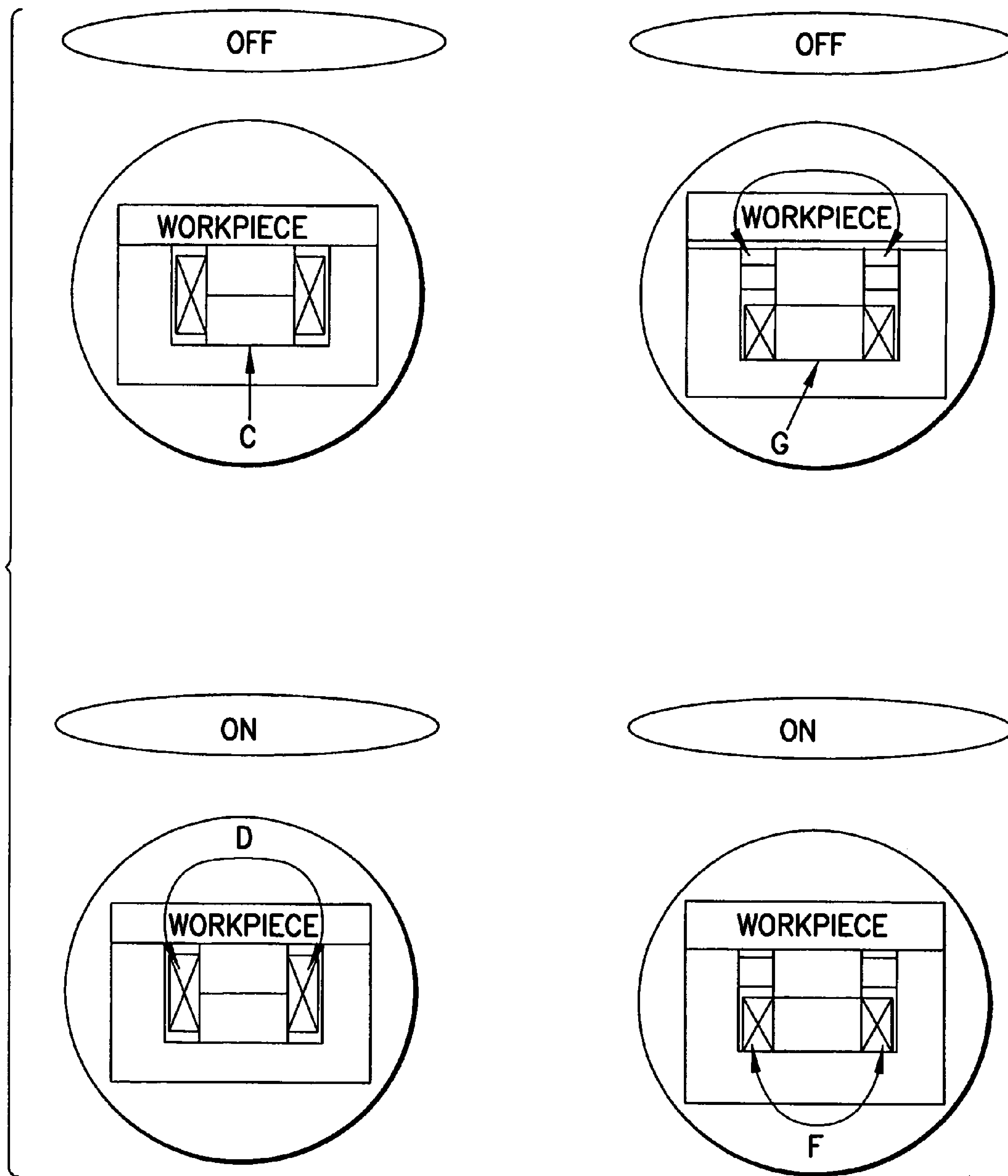


FIG.17

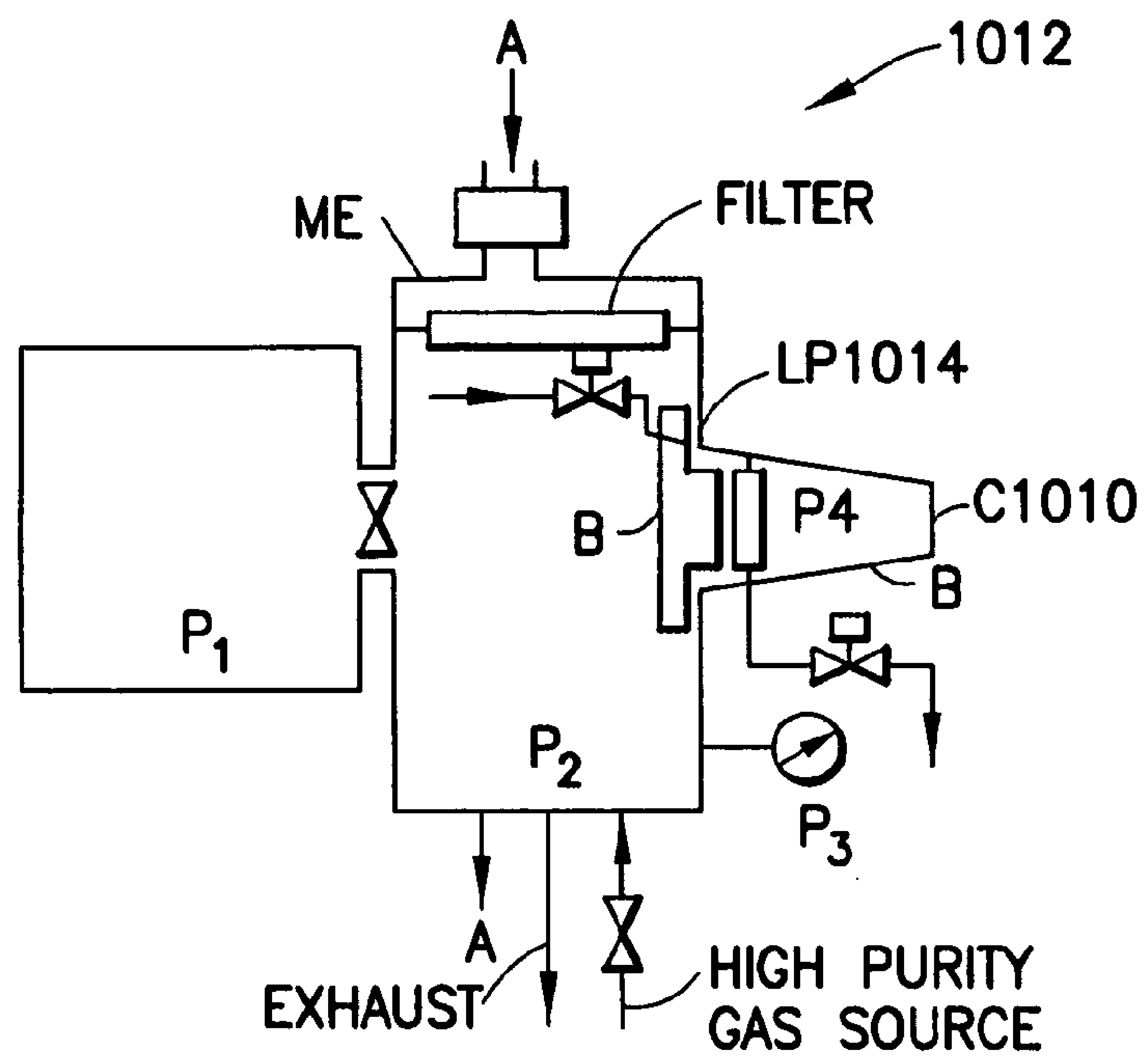
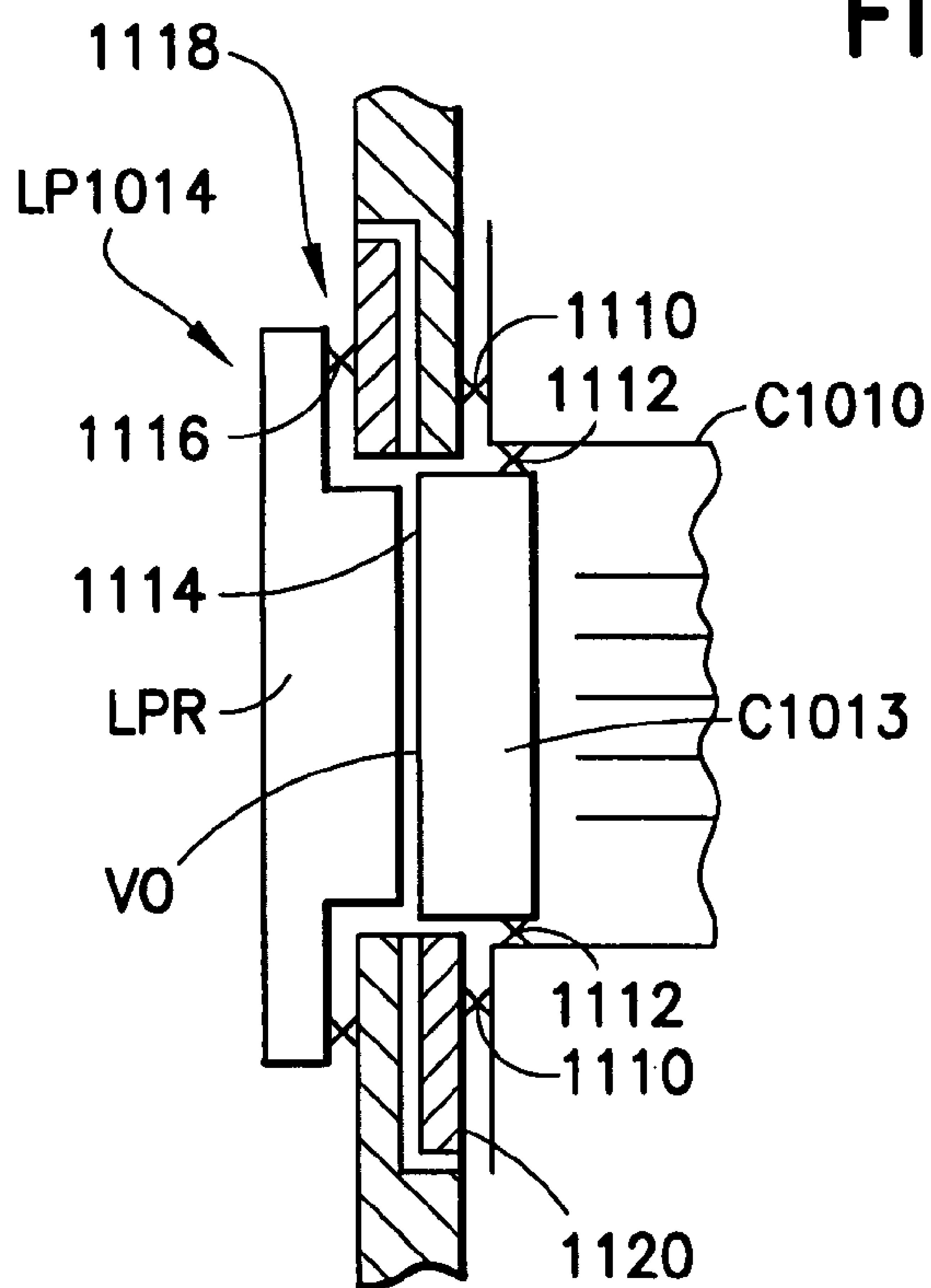


FIG.18



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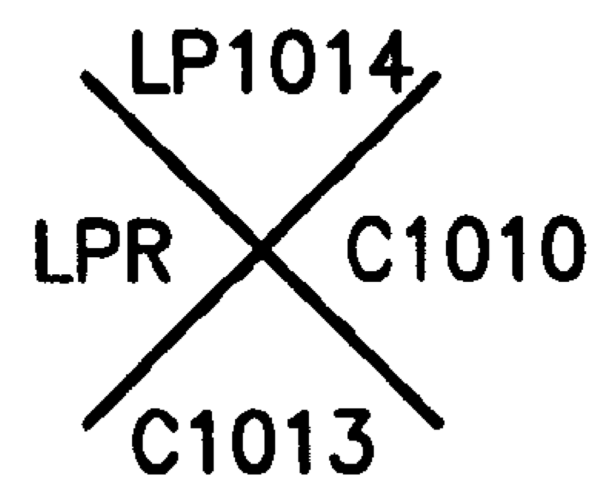


FIG.18B

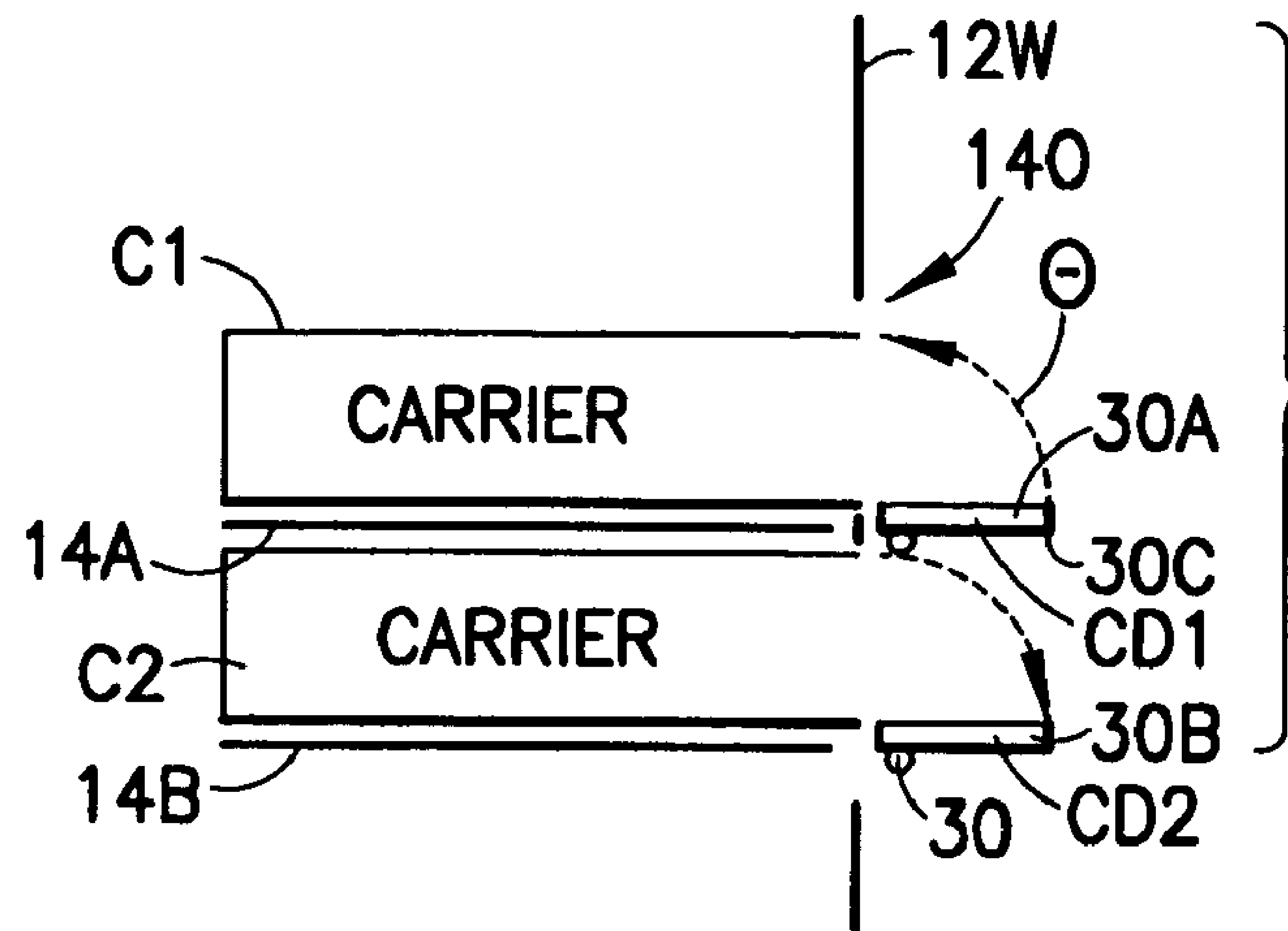


FIG.19A

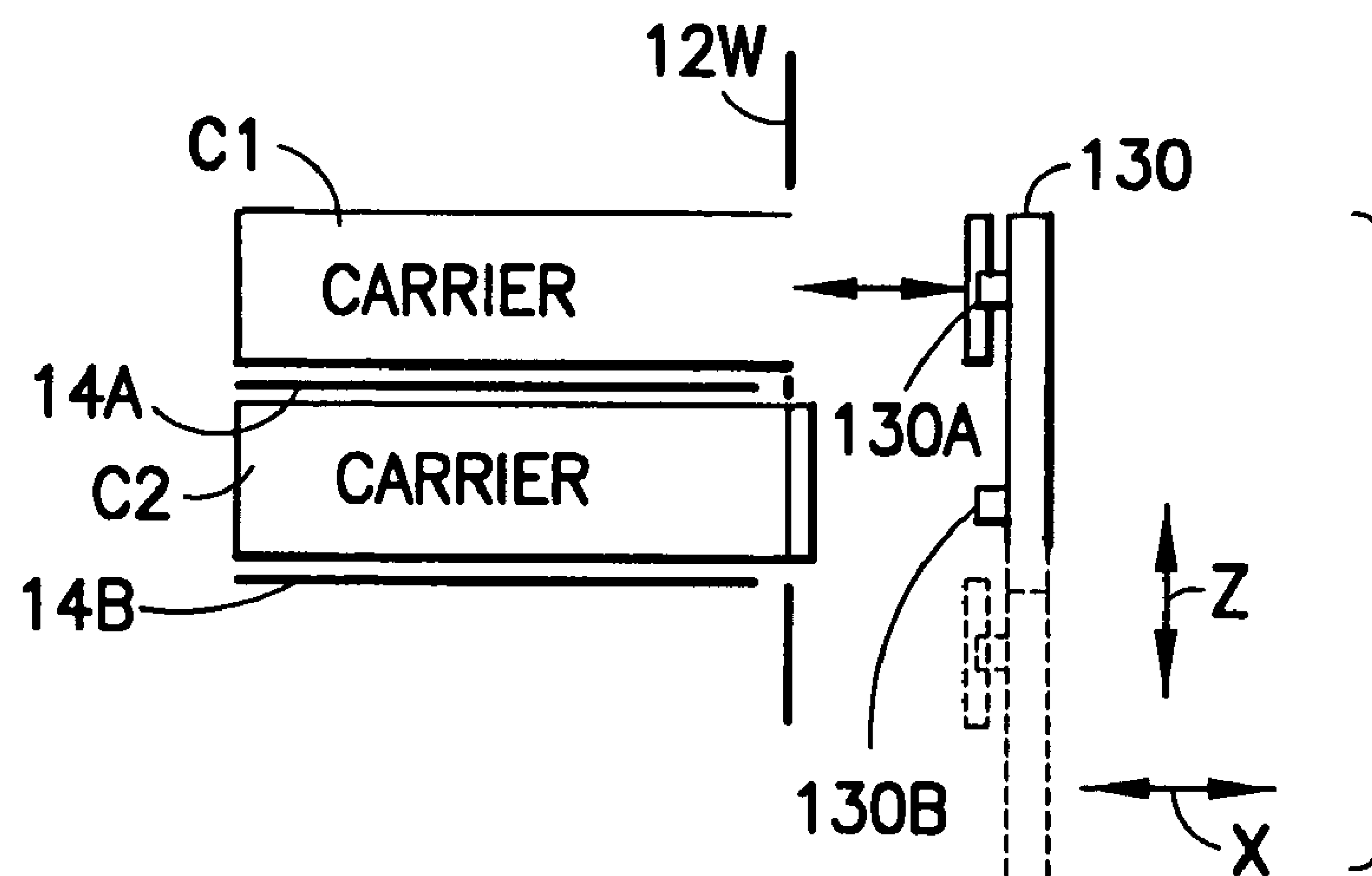


FIG.19B

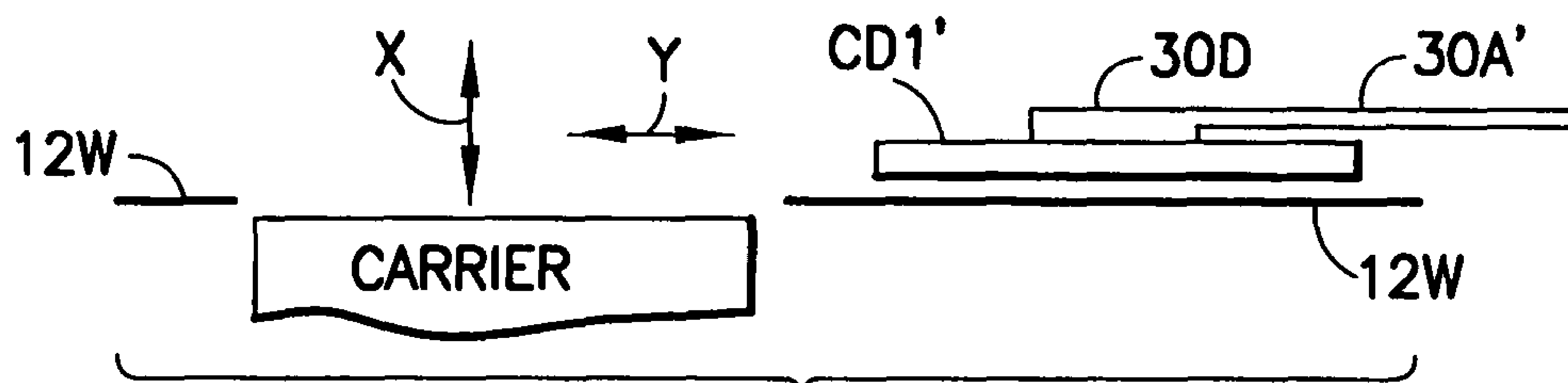


FIG. 19C

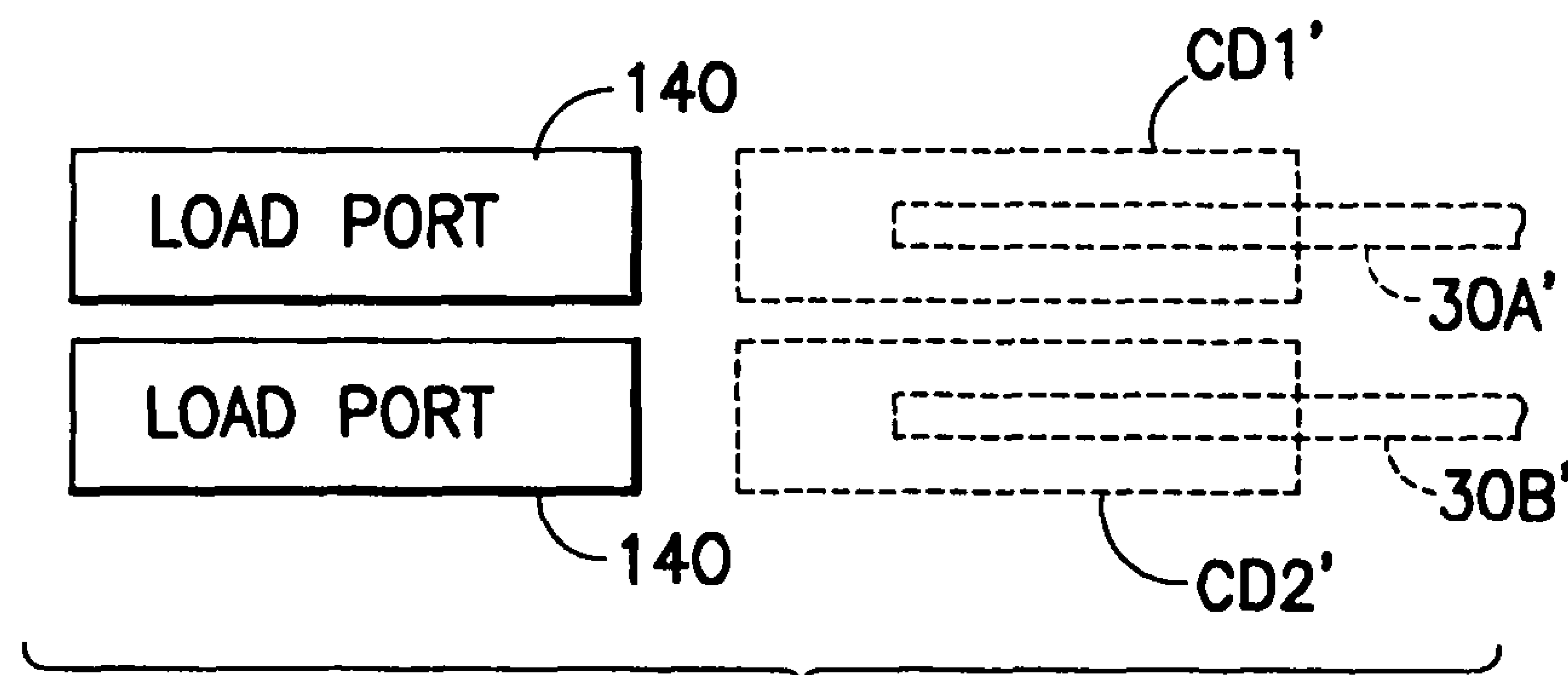


FIG. 19D

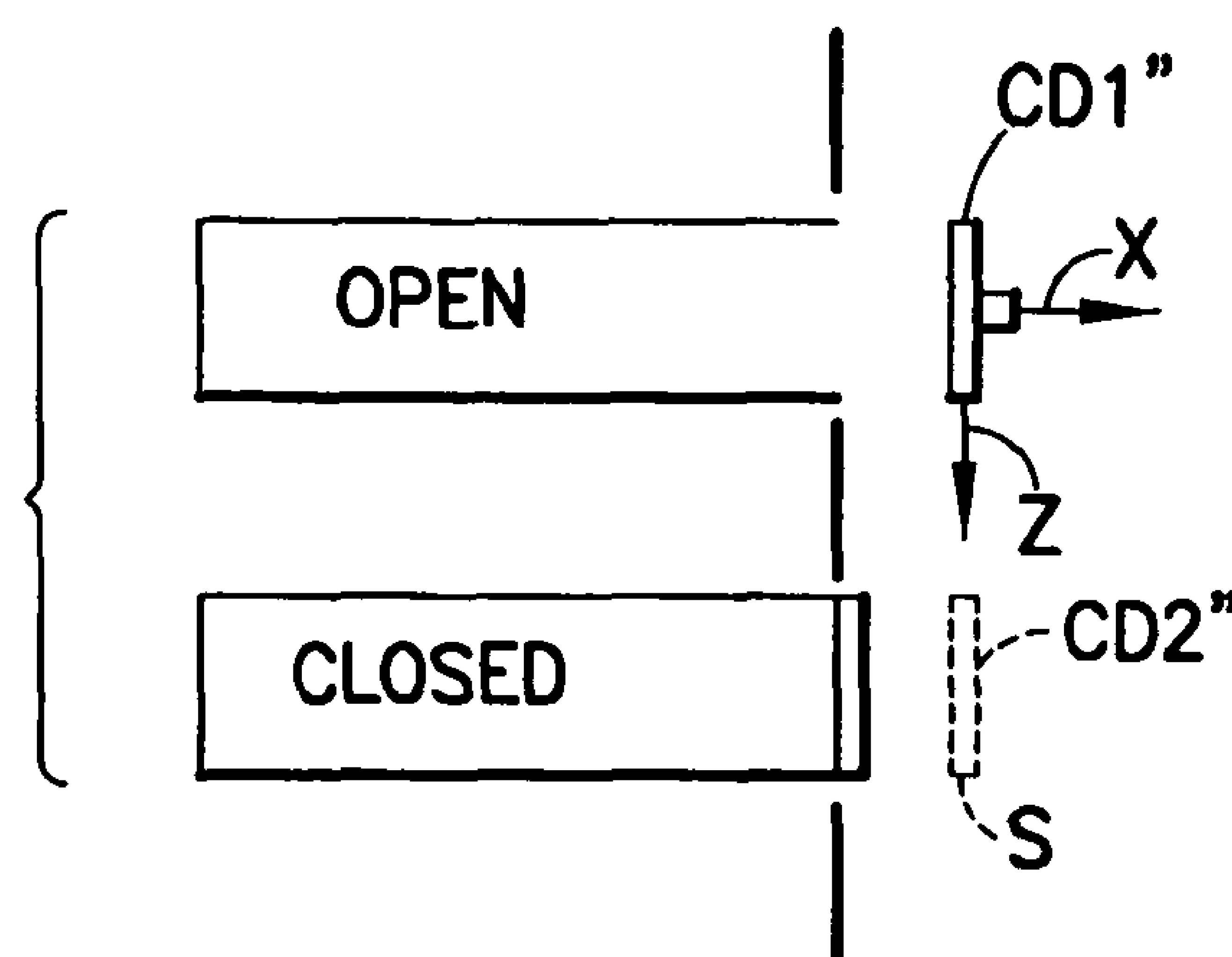


FIG. 19E

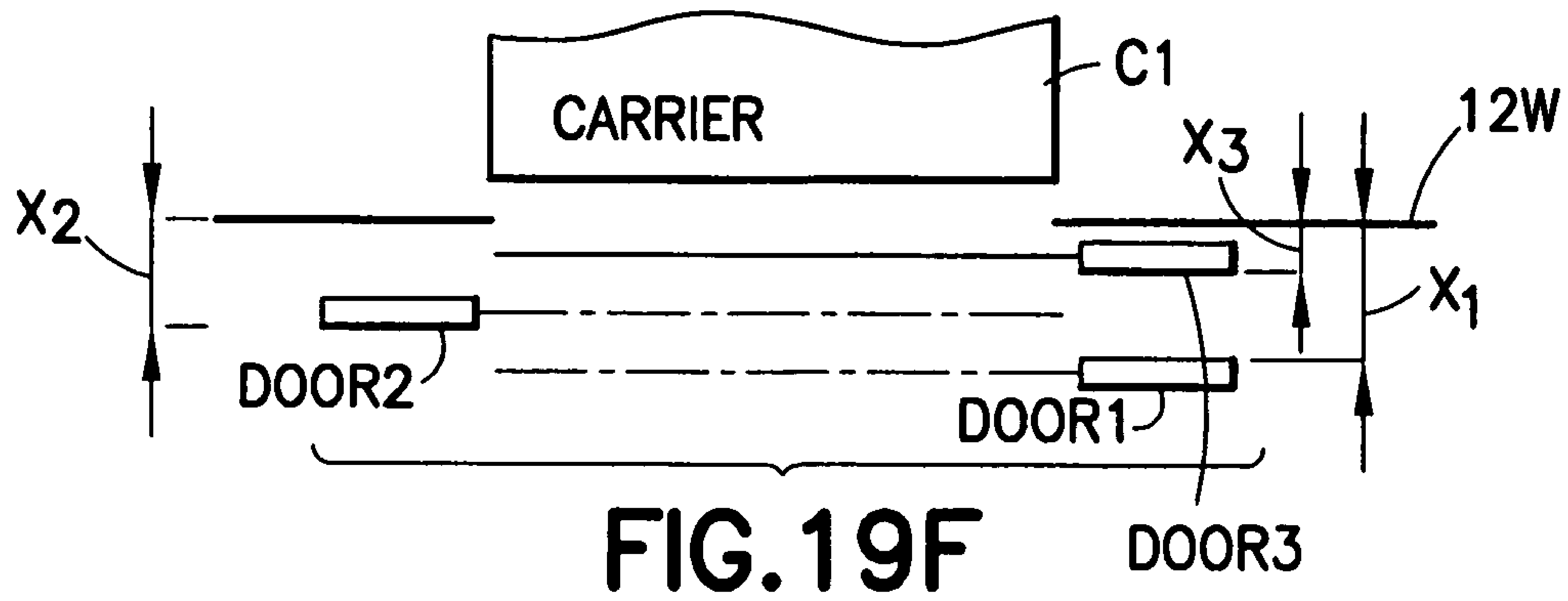


FIG.19F

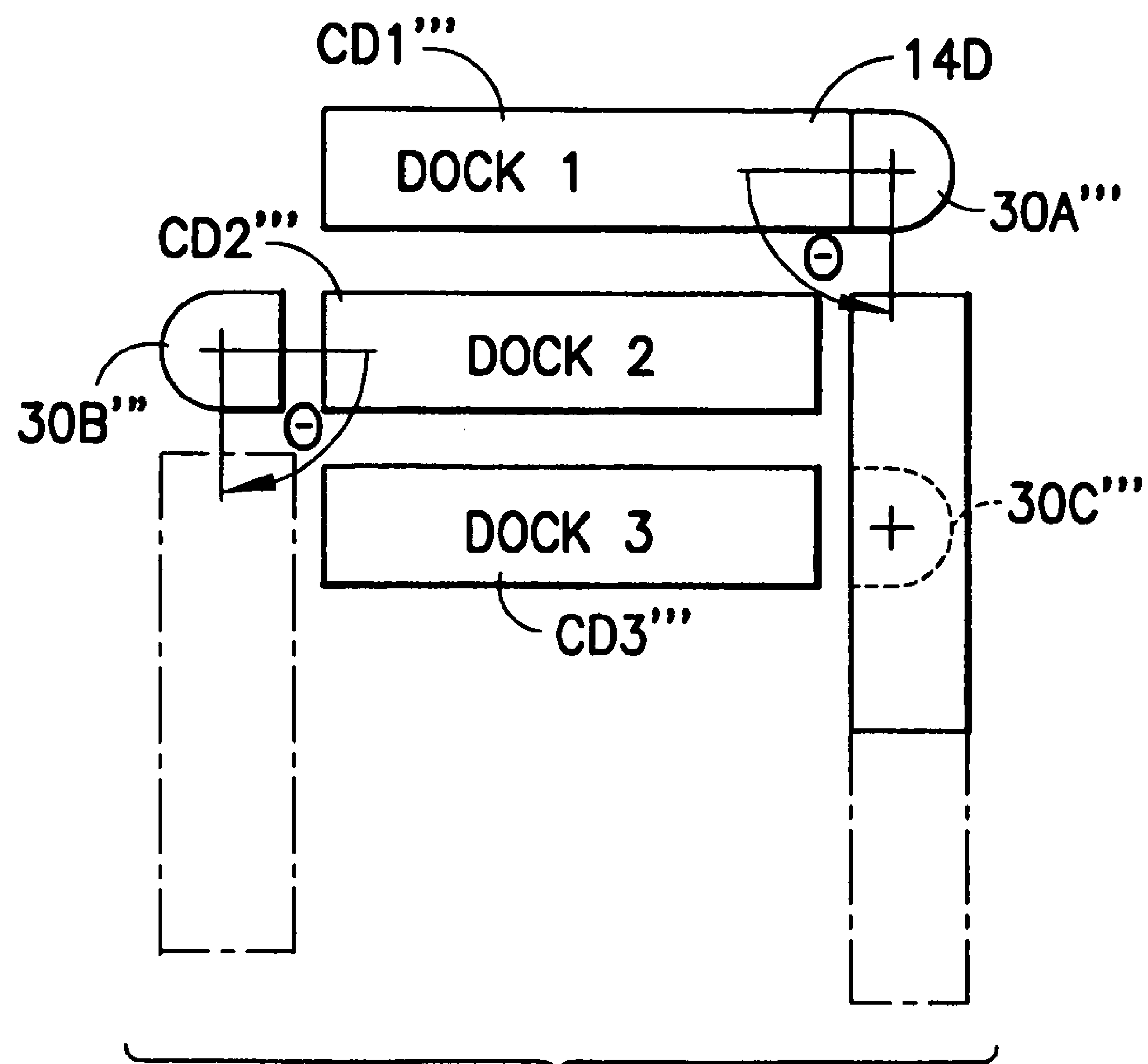


FIG.19G

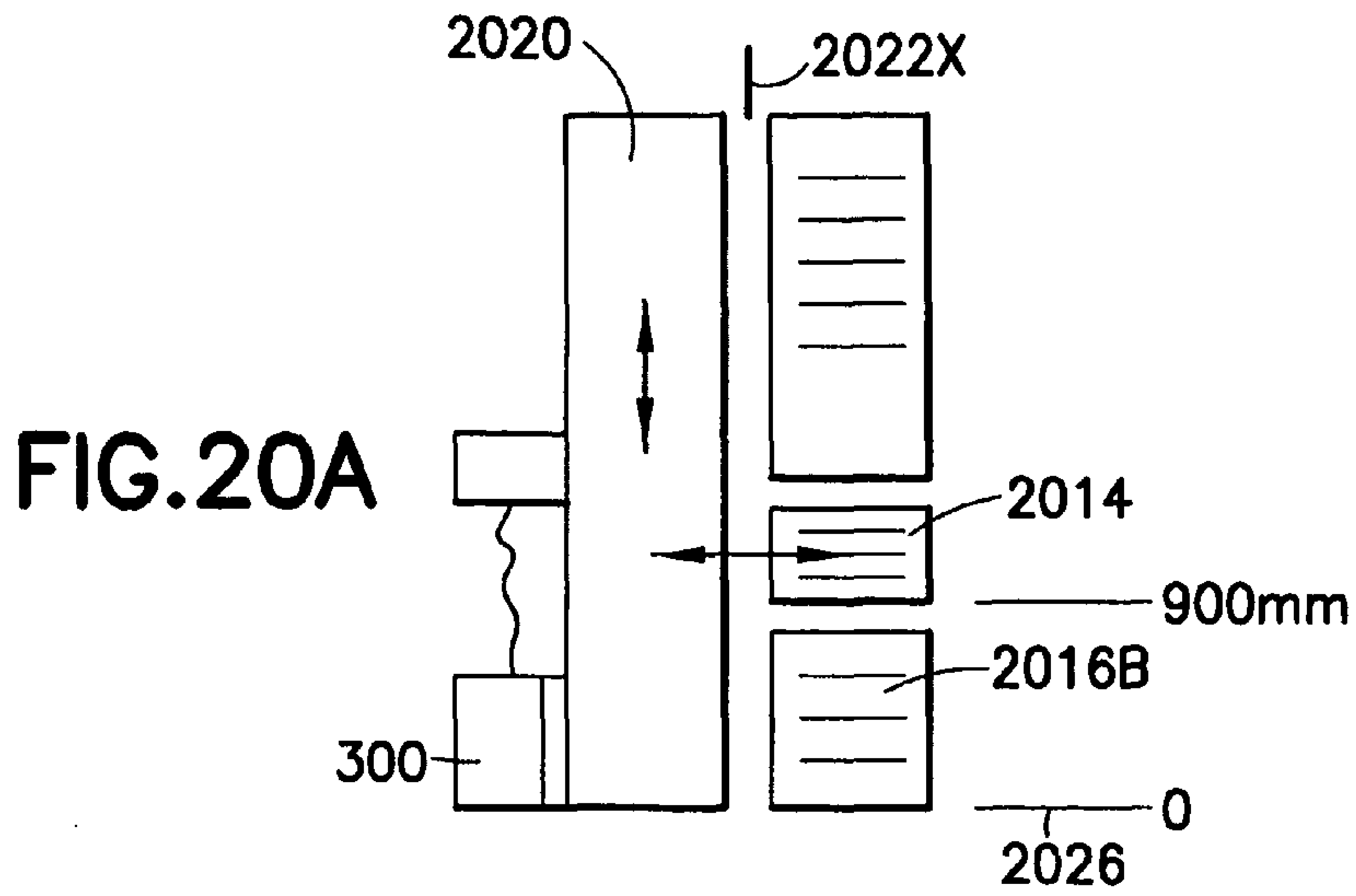


FIG.20A

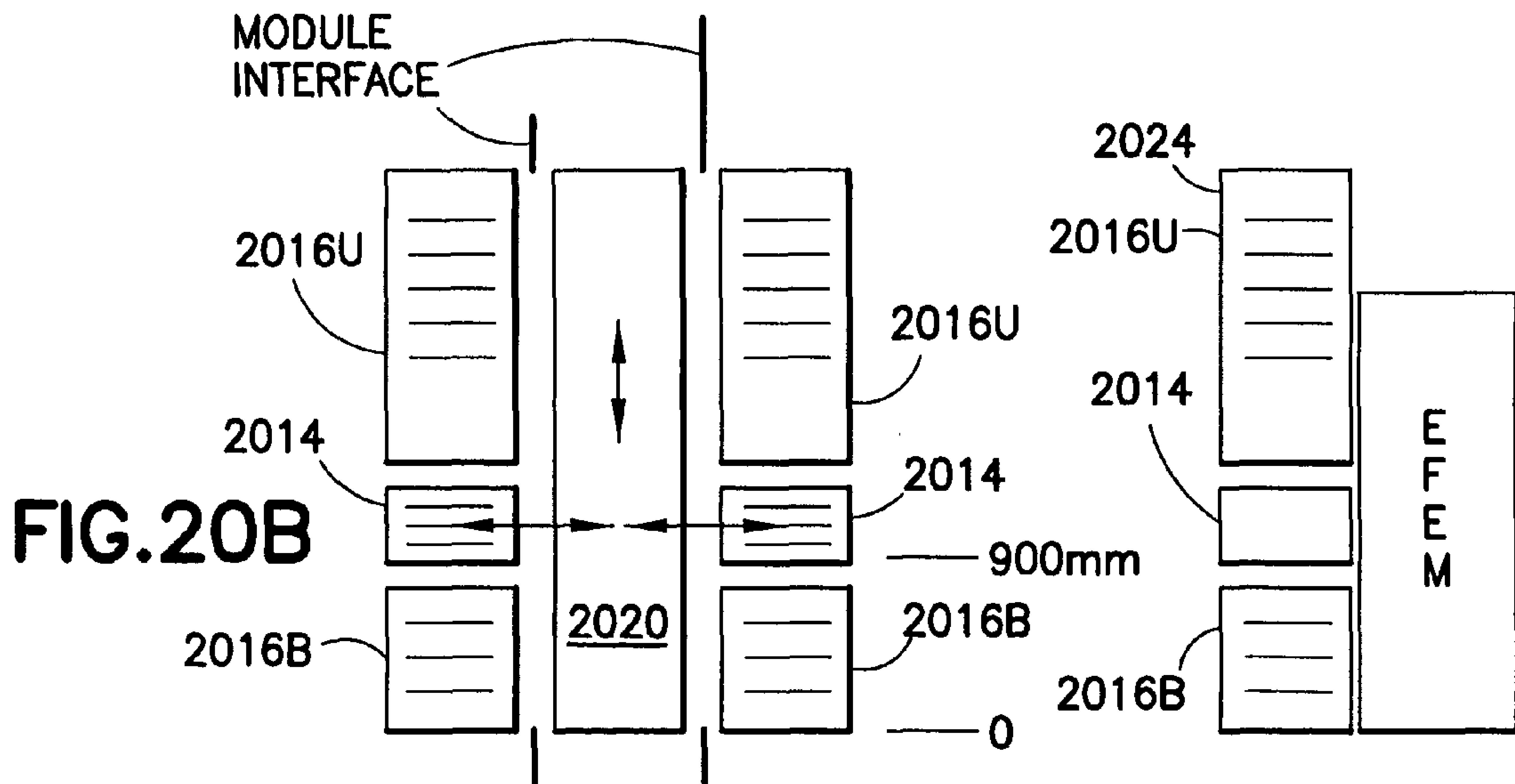


FIG.20B

FIG.20D

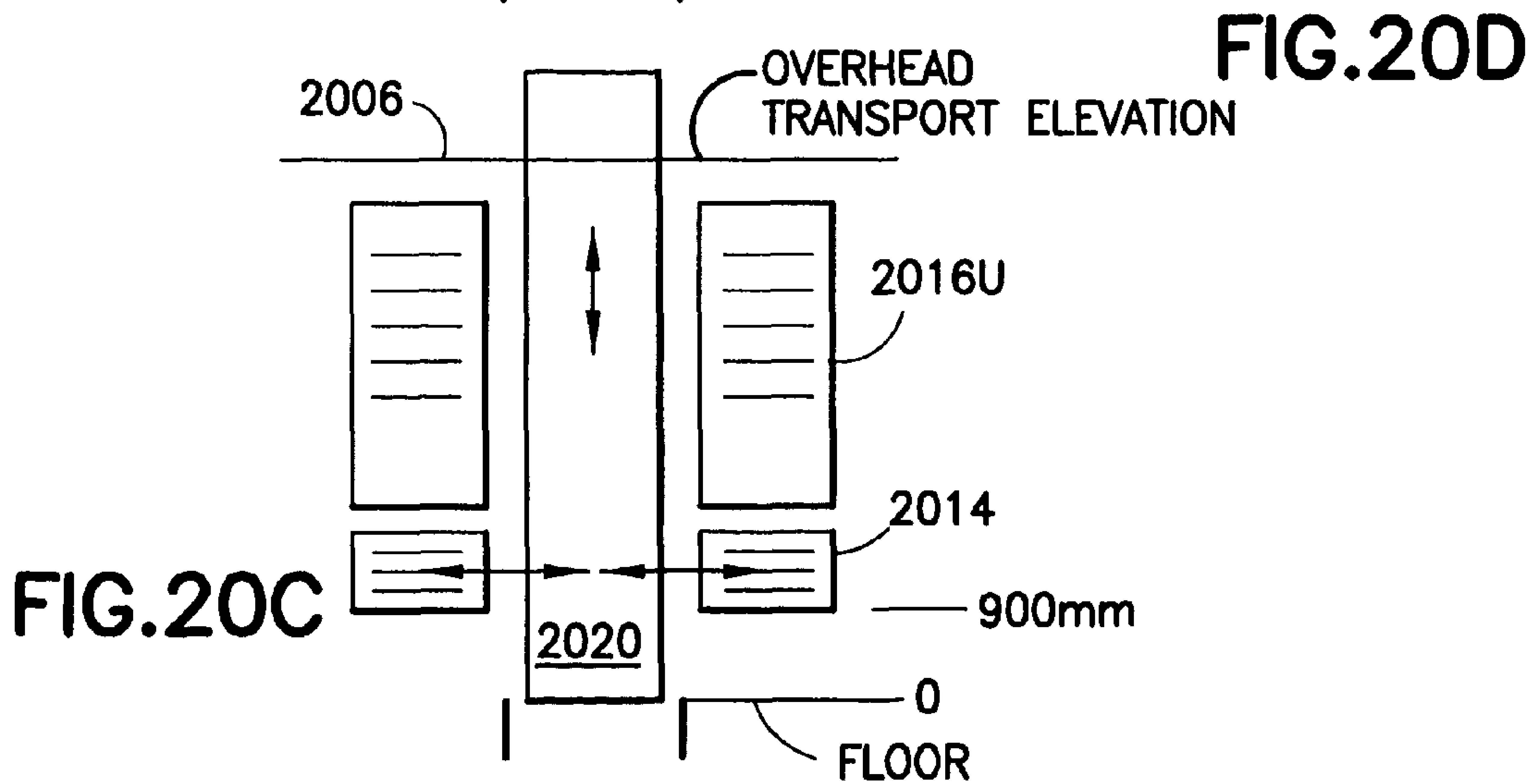


FIG.20C

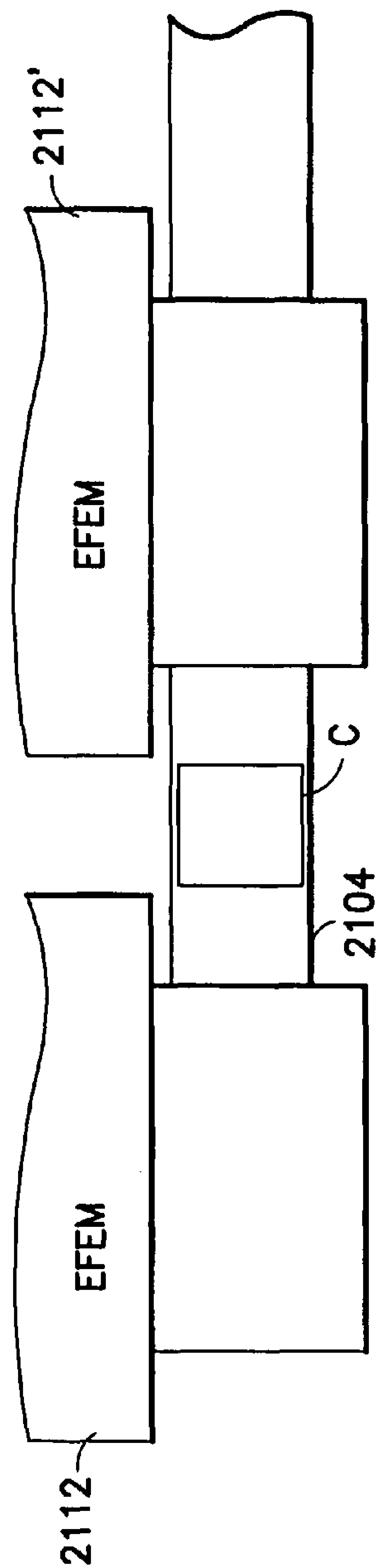


FIG.21A

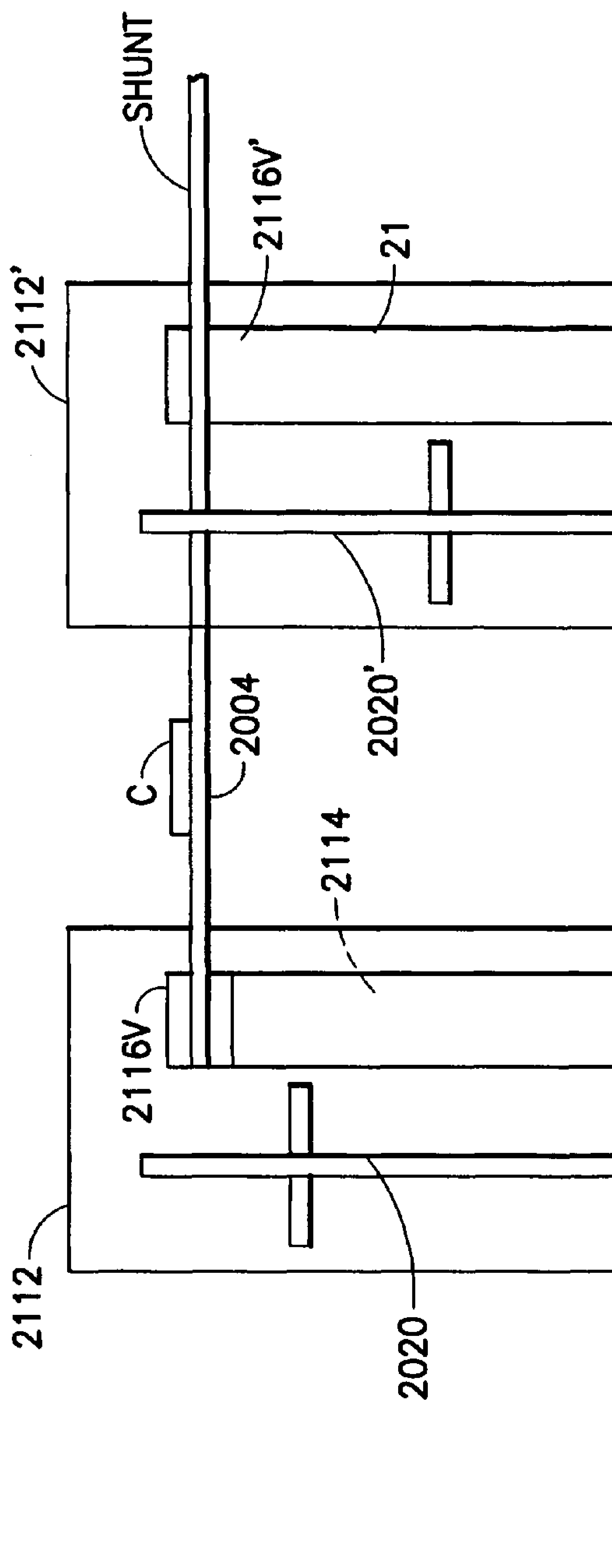


FIG.21B

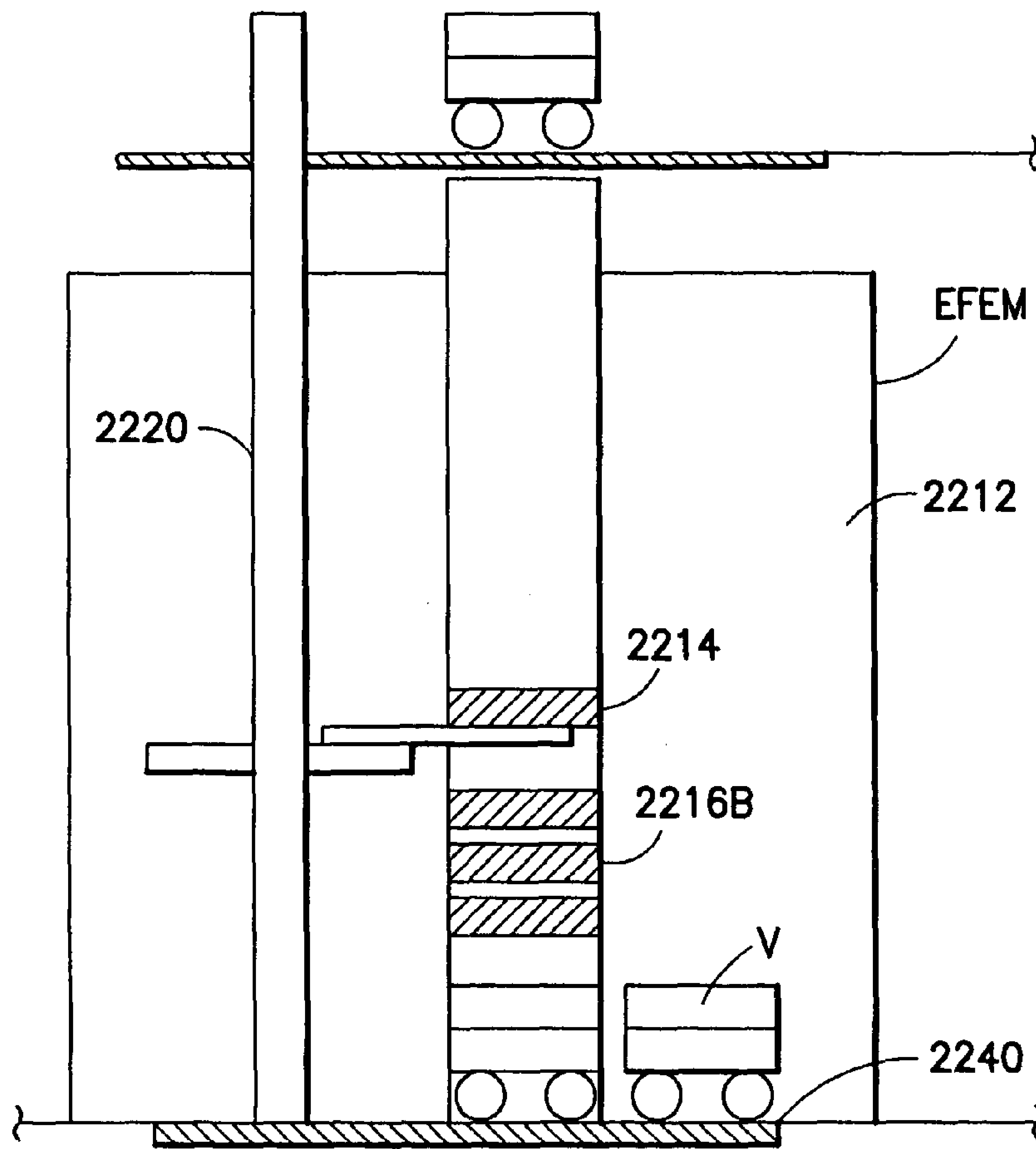


FIG.22

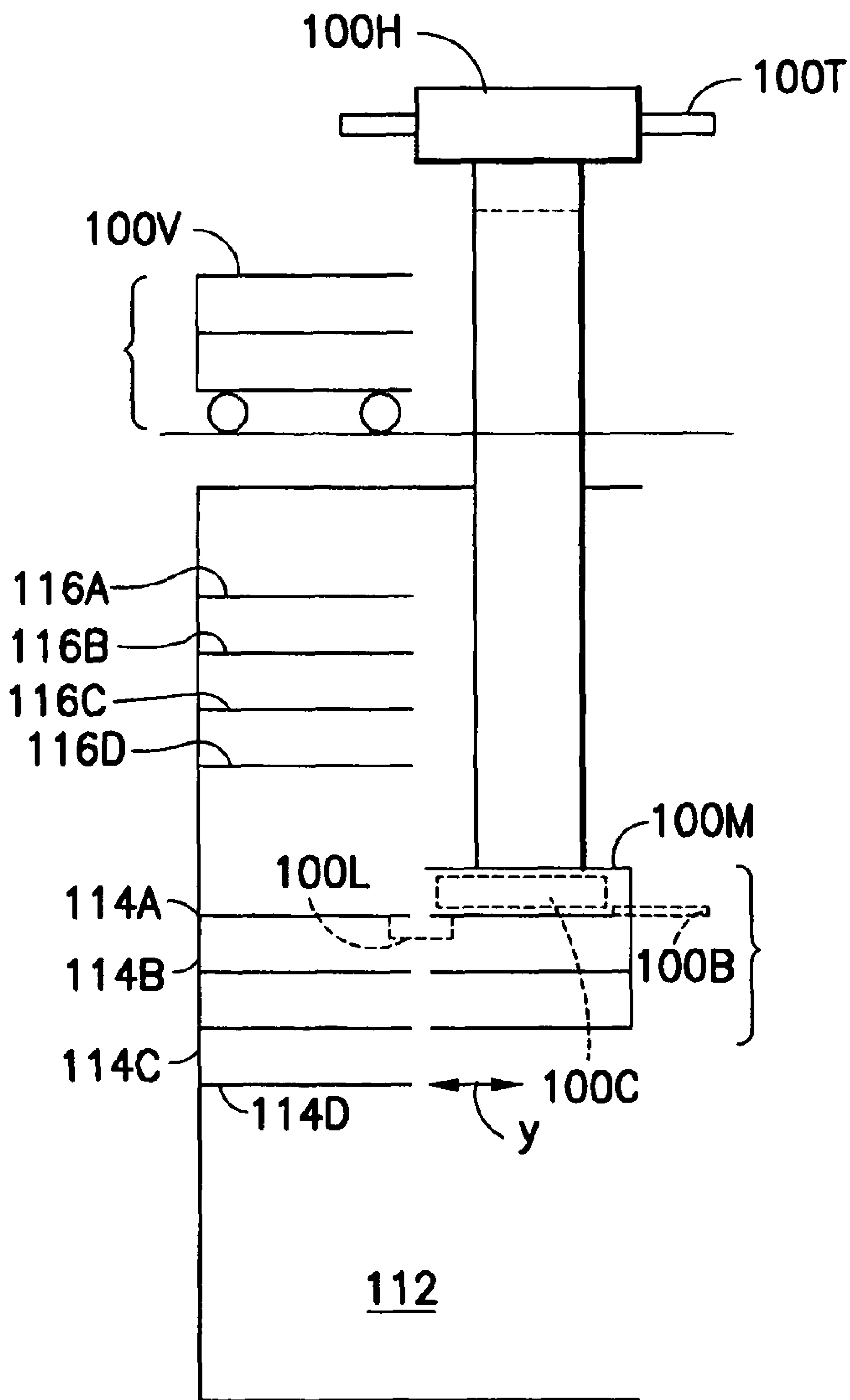


FIG.23A

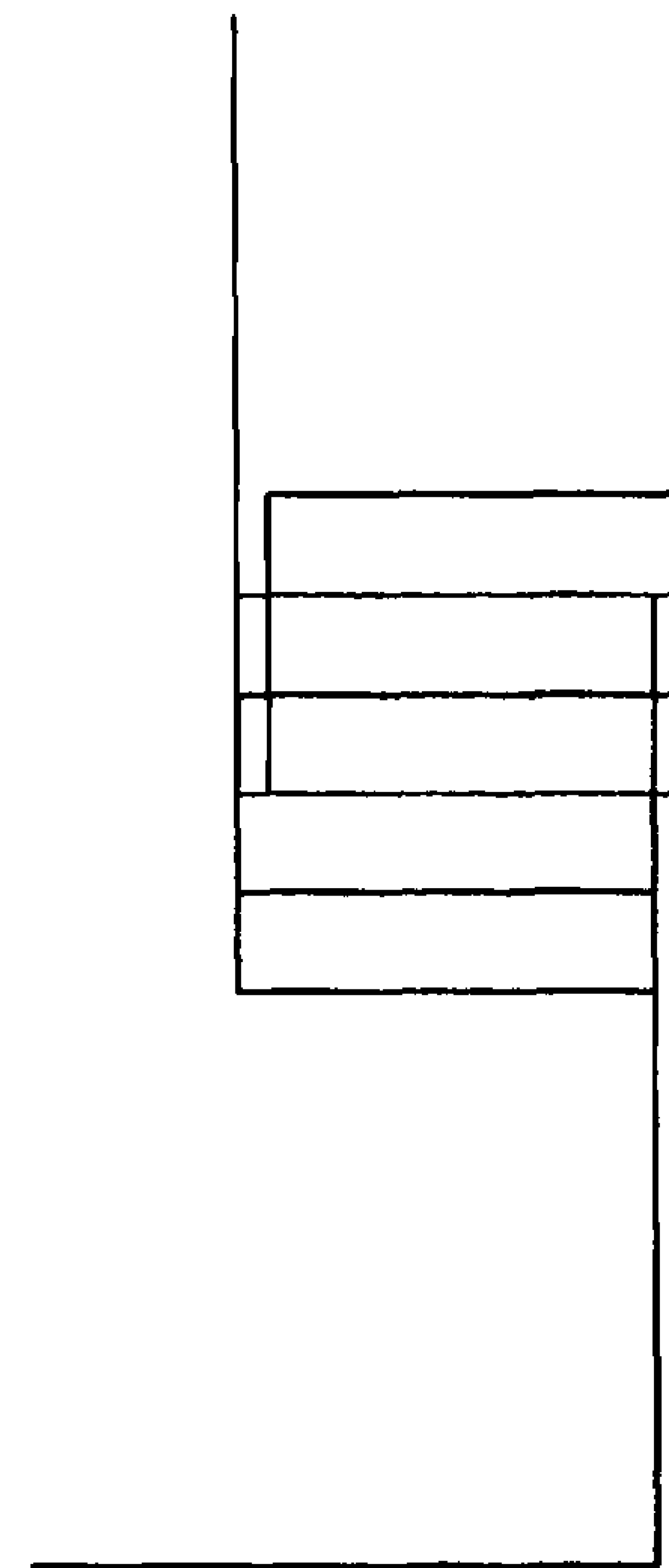


FIG.23B

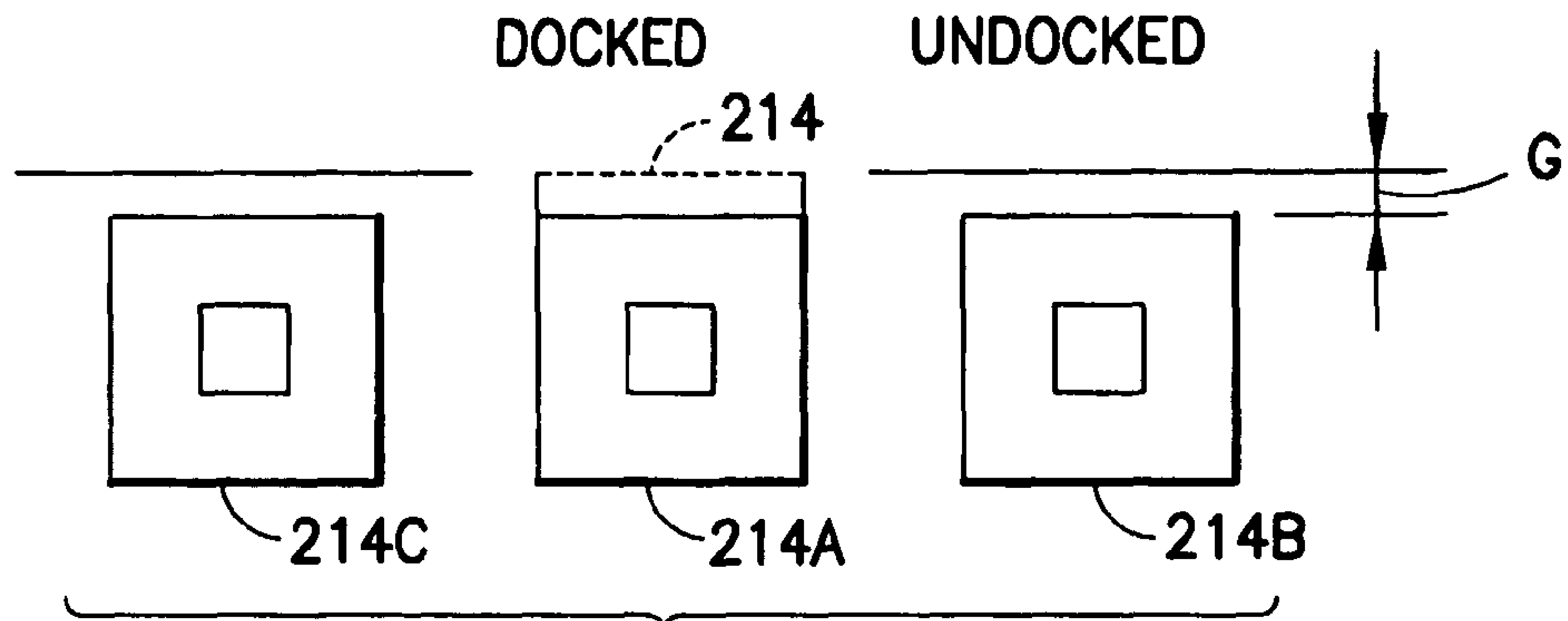


FIG.24A

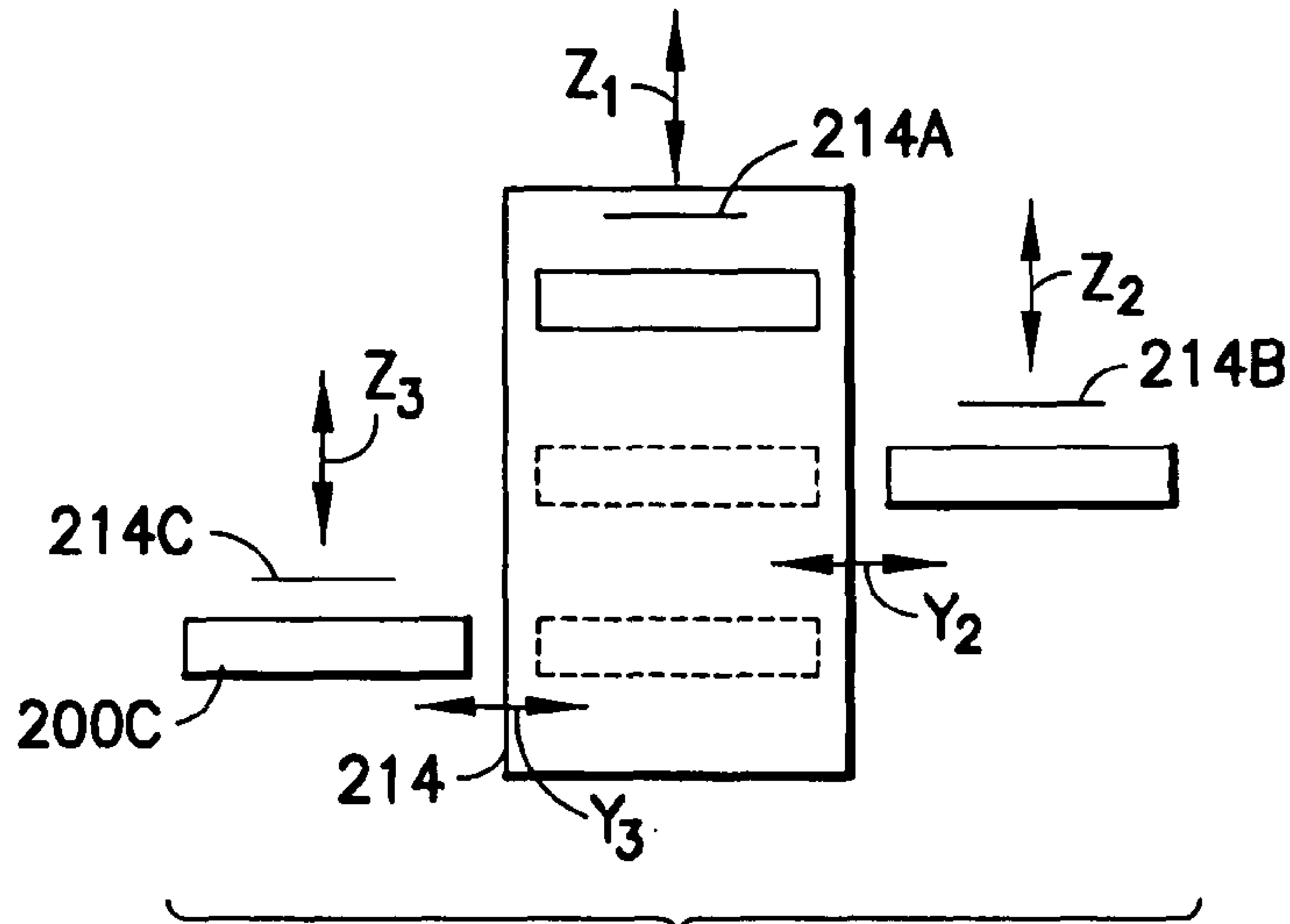


FIG.24B

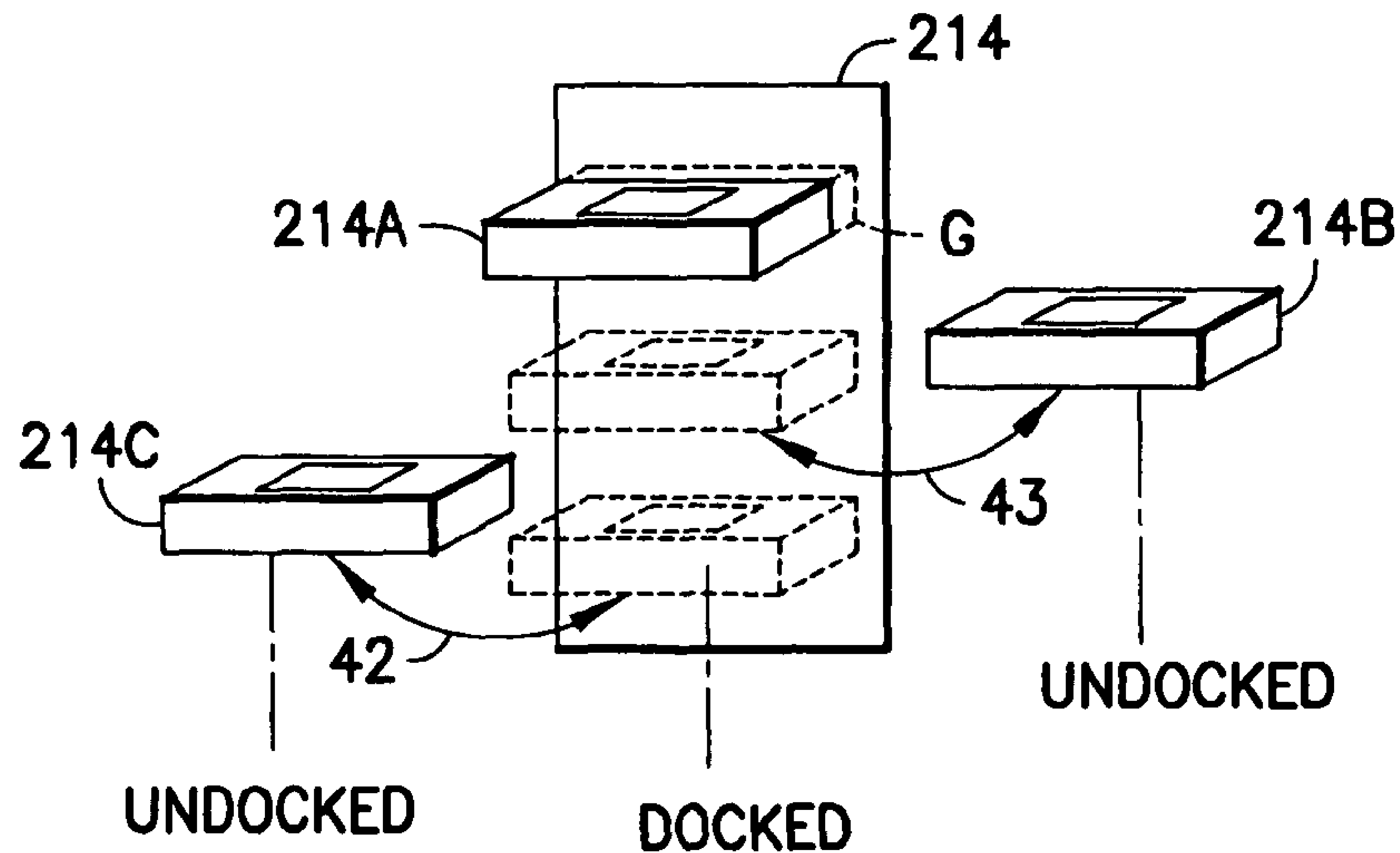


FIG.24C

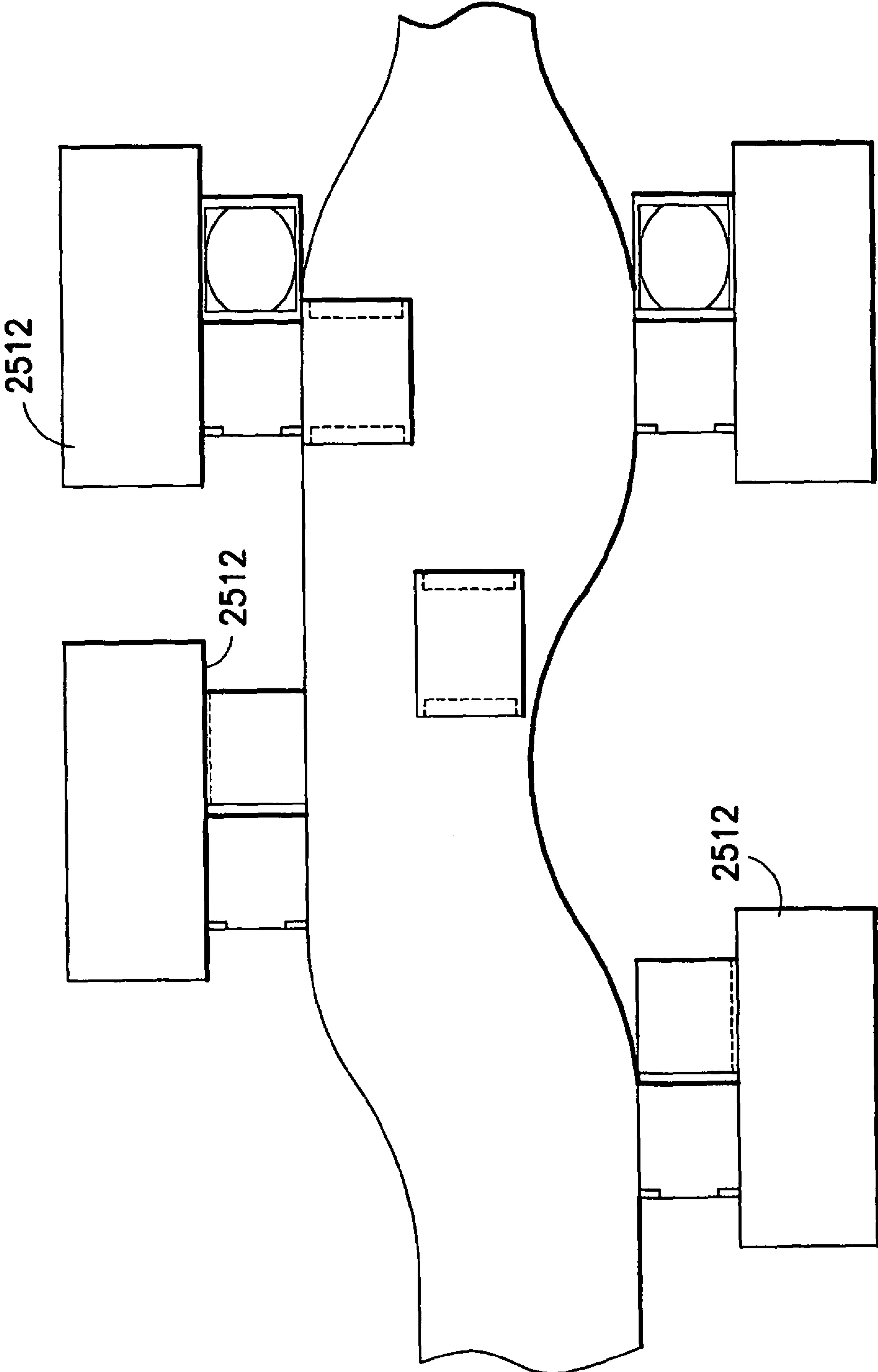


FIG.25A

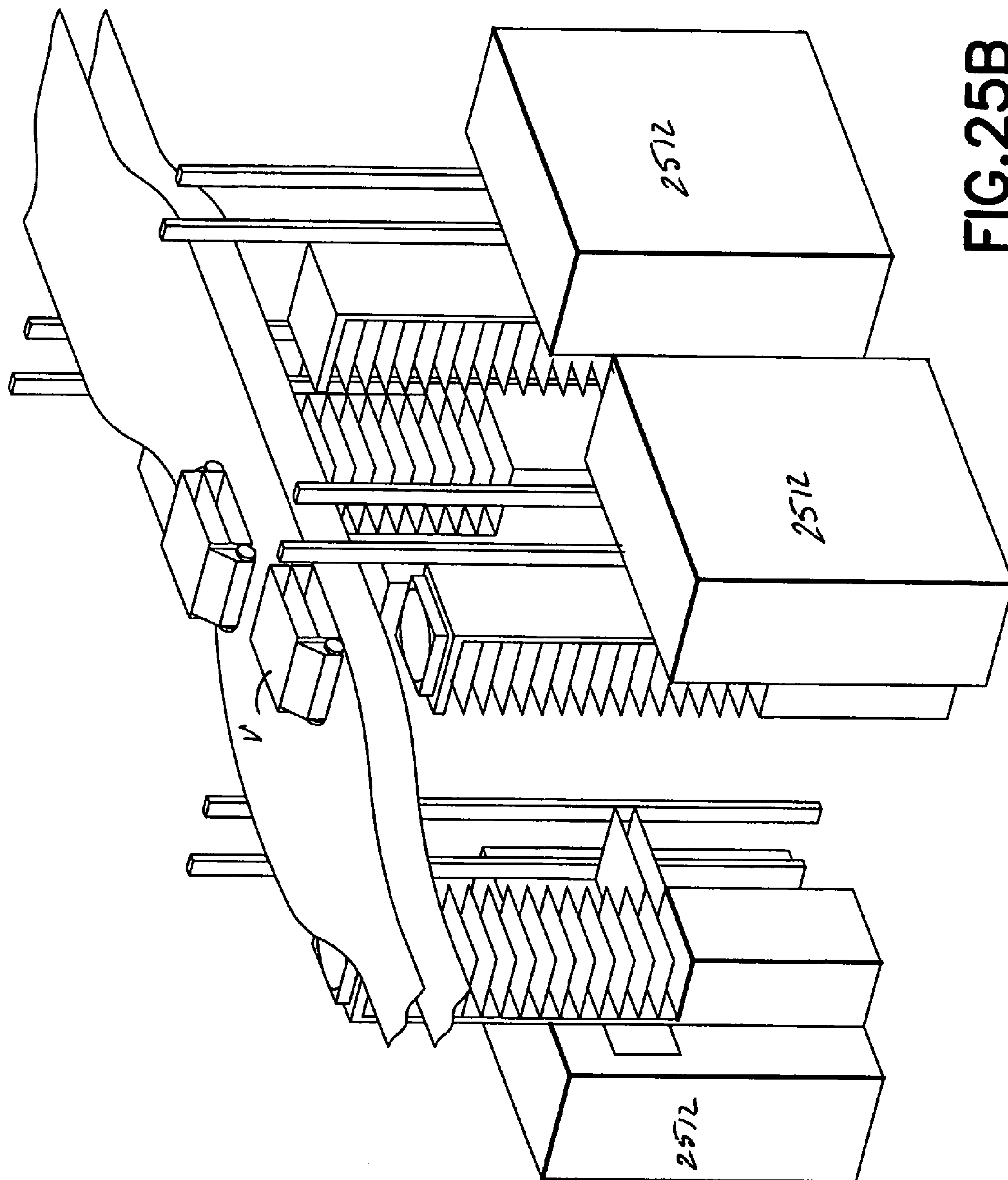


FIG.25B

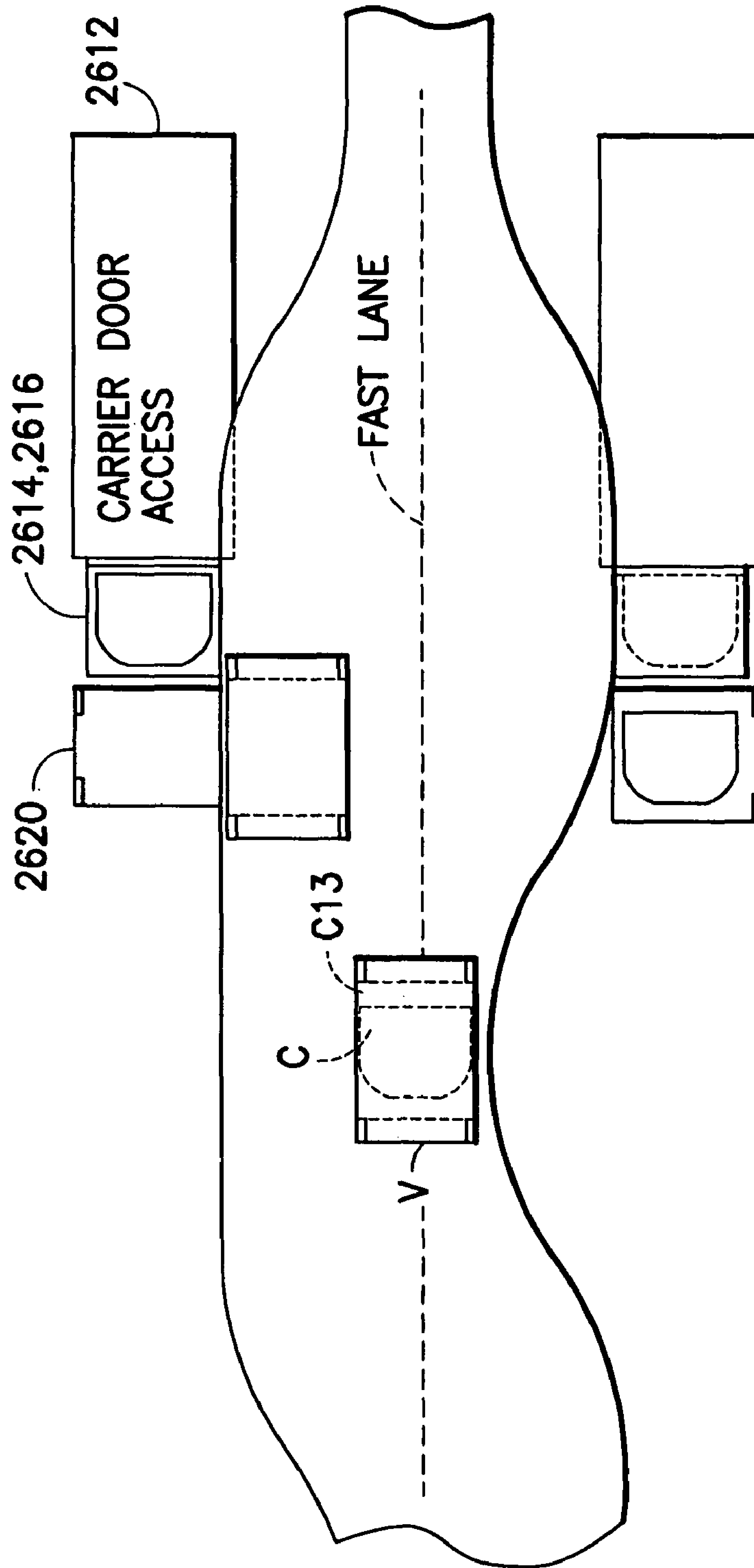
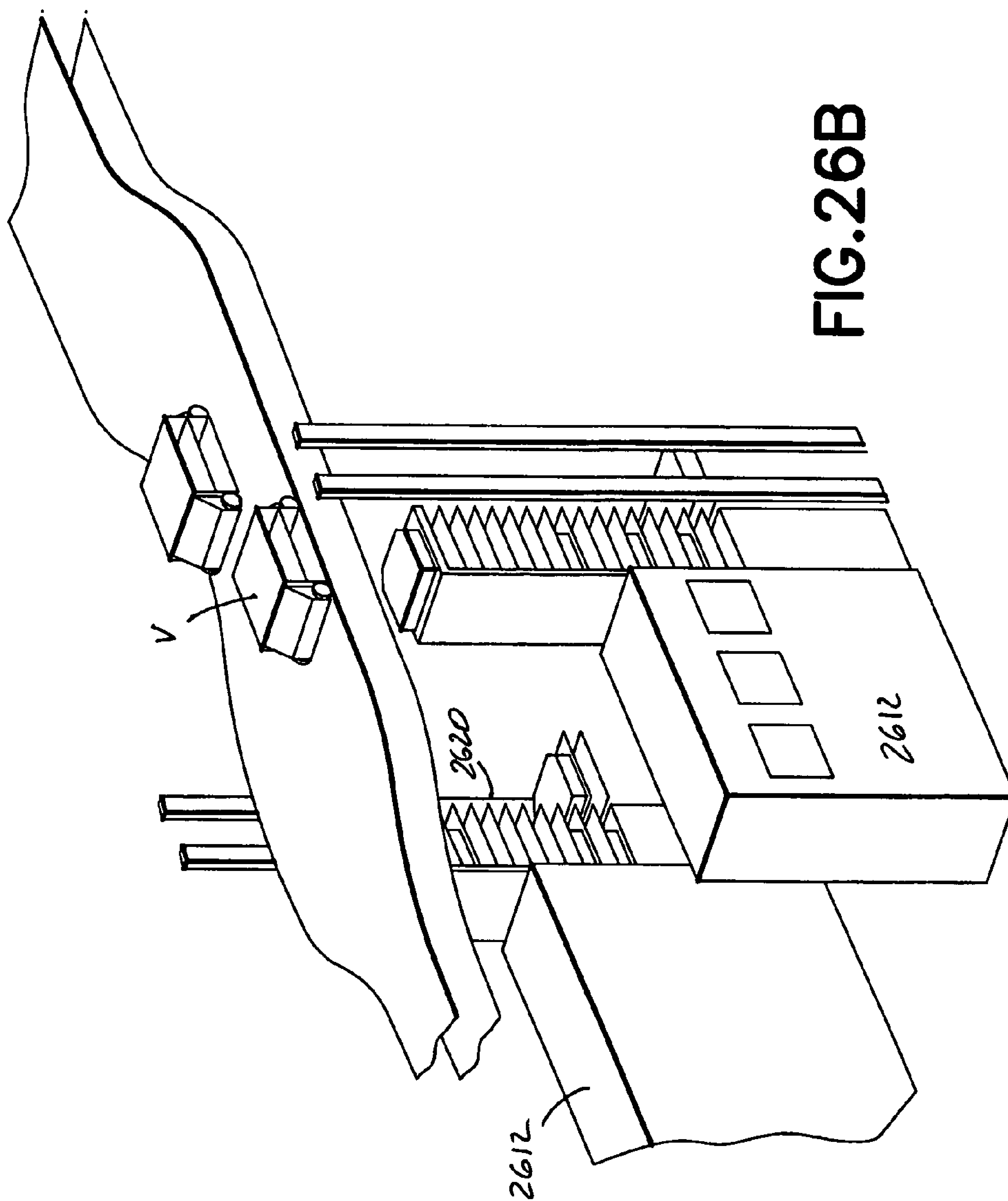


FIG.26A


V
2620
2612
2612
FIG.26B

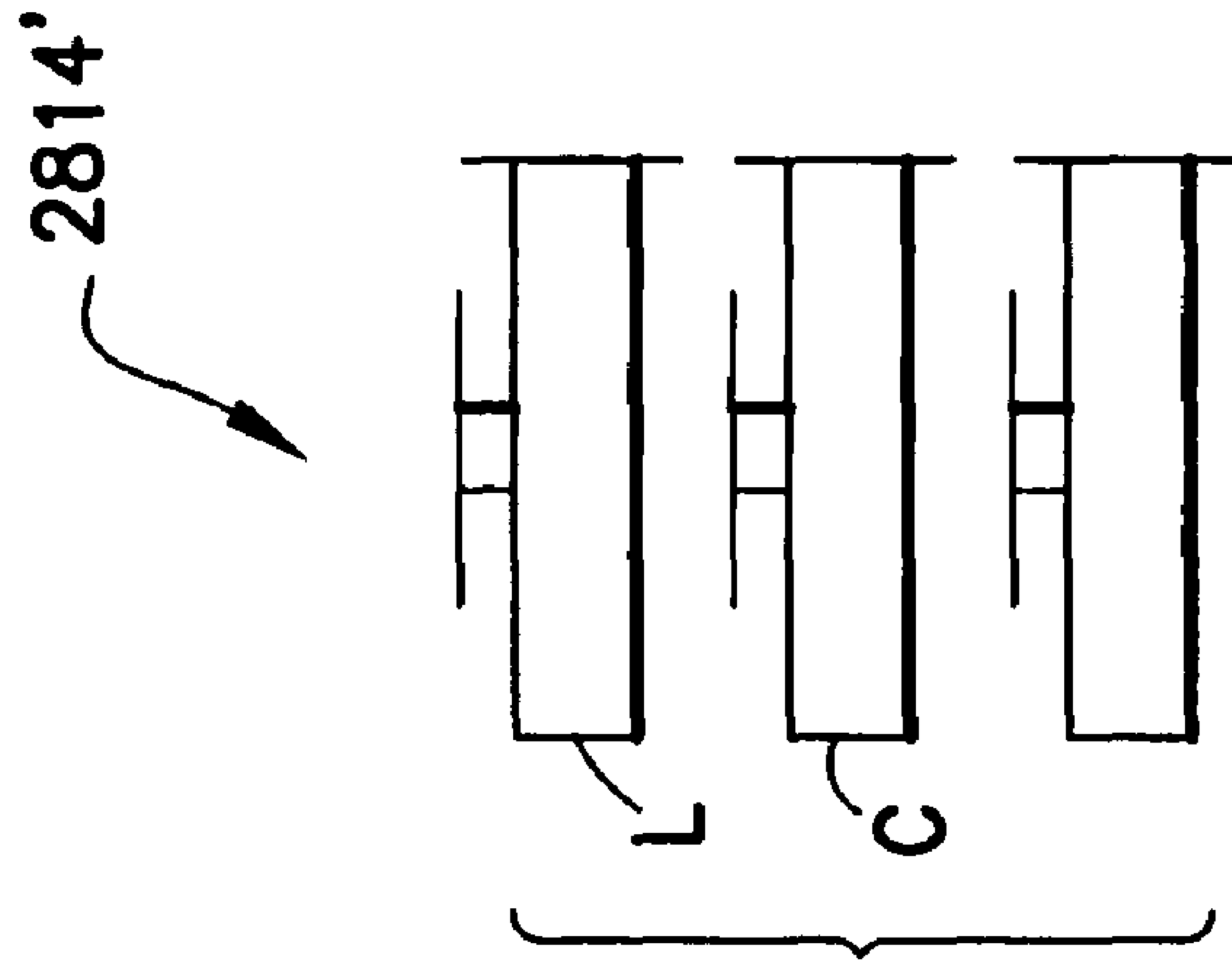


FIG.28B

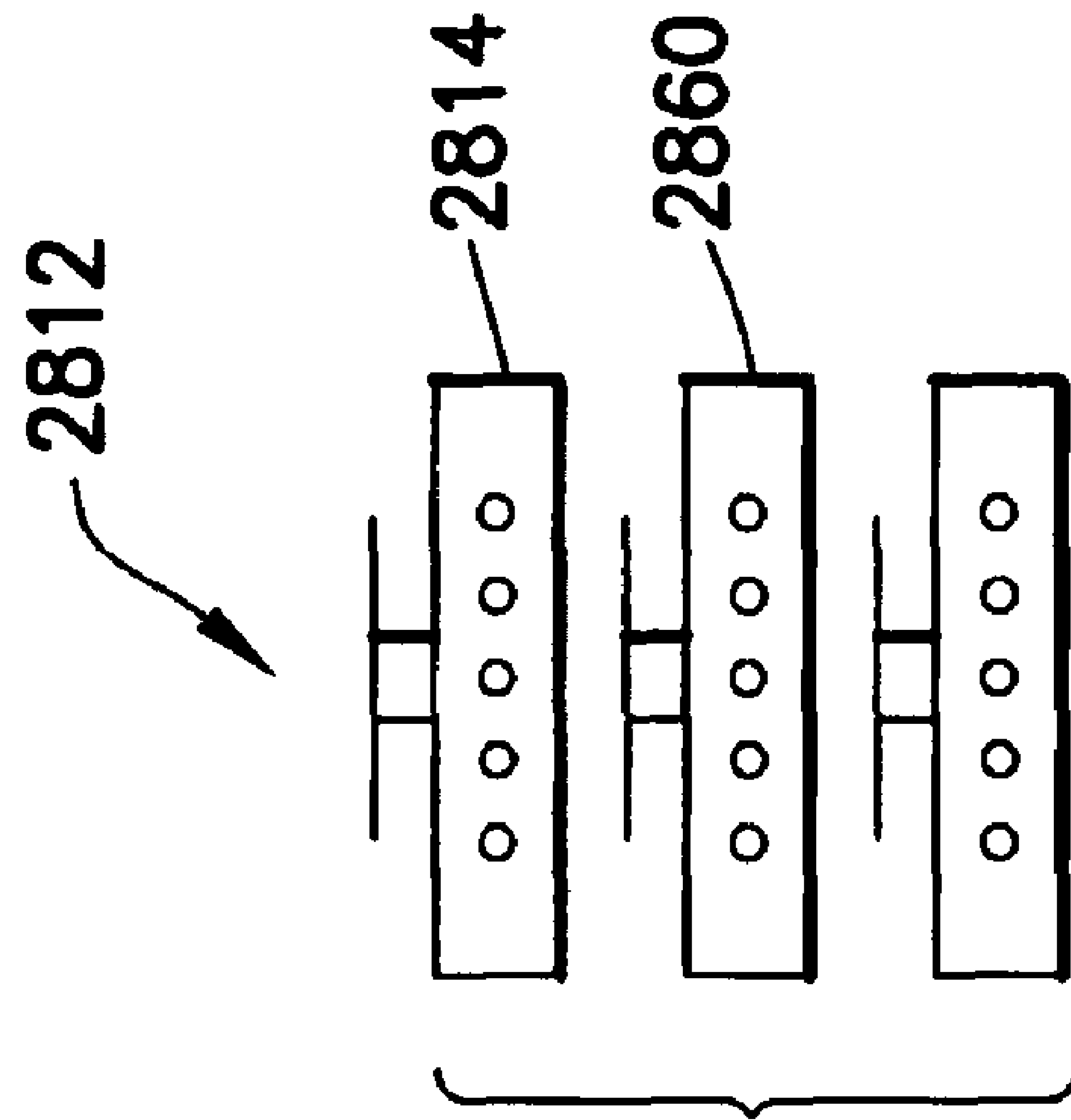


FIG.28A

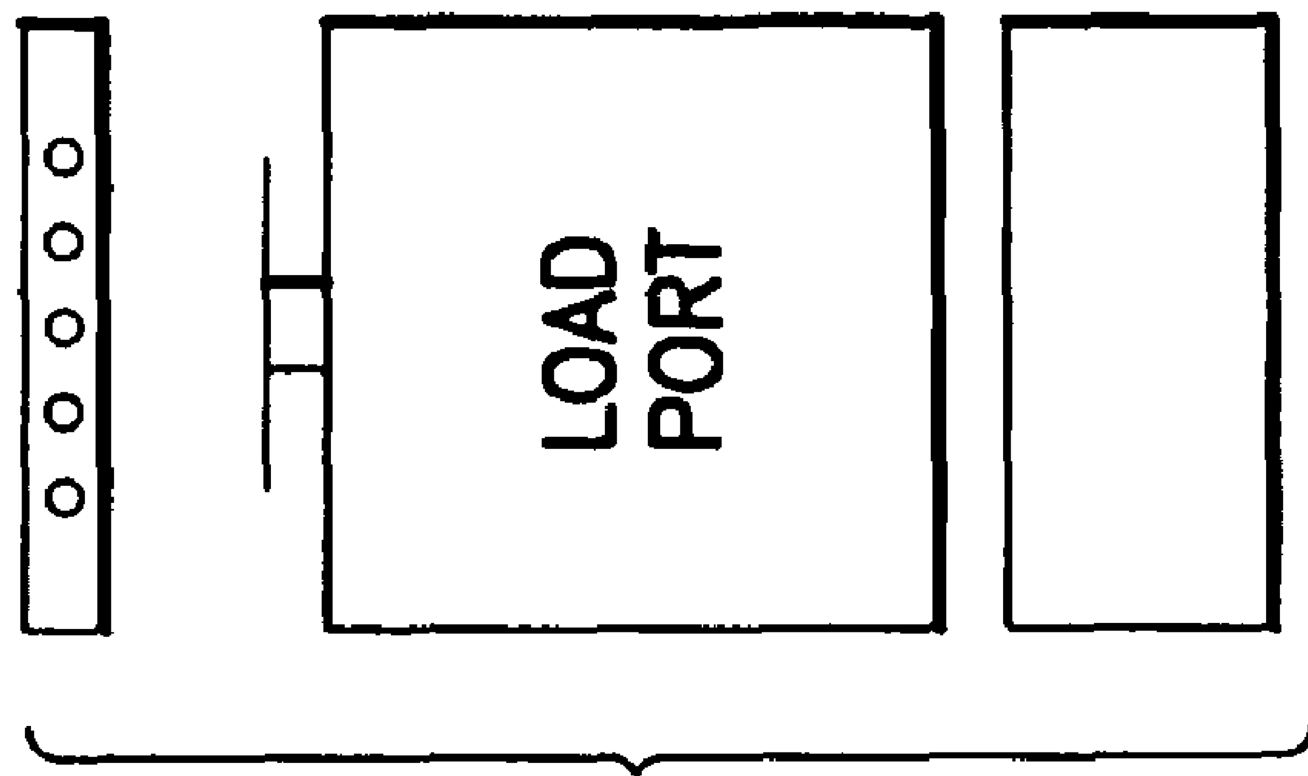


FIG.27

ELEVATOR-BASED TOOL LOADING AND BUFFERING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of U.S. Provisional Application No. 60/604,099 filed Aug. 23, 2004 which is incorporated by reference herein in its entirety.

BACKGROUND

1. Field of the Invention

The exemplary embodiments disclosed herein are related to an apparatus and method for transporting and storing reduced-capacity substrate carriers for use within an IC fab.

2. Brief Description of Related Developments

There is a desire in the semiconductor industry to reduce wafer cycle time through the fab and reduce the amount of work in progress as well as to improve wafer safety. Studies have shown that by moving to a single wafer carrier, wafer cycle time and WIP (wafers in process) is significantly reduced. In addition for the next generation wafer size (450 mm) the ITRS roadmap calls for single substrate carriers. Benefits of using single wafer or reduced capacity carriers include WIP reduction, process changeover time reduction and product ramp time improvement. Problems arise where single substrate carriers are employed relative to the ability of both the process tool and material transport system to effectively maintain the higher pace of the factory due to the larger number of carrier transport moves as compared to 13 or 25 wafer carriers. One example of such a problem includes where there is only one slot. It is desired that the robot in the process tool have the capability to quickly swap (fast swap) the wafer in the carrier so the carrier may be able to be replaced with another carrier that has an unprocessed wafer to keep the tool busy. Many such tools do not have the ability to fast swap, as in the case of a conventional single blade three axis robot. Another example of such a problem includes where there is only one slot. It is desired that the material transport system transporting carrier to tools in the IC FAB have the capability to supply carriers, at a high rate and quickly swap the carriers at the process tools load port(s) so that one carrier at the tool may be able to be replaced with another carrier that has an unprocessed wafer to keep the tool busy. Many such material transport systems do not have the ability to supply carriers at a high rate or with the capability to fast swap, as in the case of a conventional (overhead transport) OHT based material transport systems as implemented in conventional 300 mm fabs.

Conversely conventional load ports, or carrier to tool interfaces, of conventional processing tools are not capable of handling (i.e. receiving, interfacing or reading for removal) a high rate supply of carriers desired when employing reduced capacity carriers in the FAB. One example of a conventional carrier to tool interface is disclosed in U.S. Patent Publication US 2003/0044261, published Mar. 6, 2003, wherein the semiconductor material handling system is an EFEM that may be mounted or integrated to the front end of a processing tool. The conventional EFEM disclosed has carrier (FOUP) I/O ports and pod advance plates corresponding to the I/O ports that register and shuttle pods for docking/undocking to the I/O ports. The above noted example is representative of conventional carrier-tool interfaces of conventional processing tools. The I/O ports to which the pods are mated (for loading/unloading substrates or wafers to the tool) are linearly or axially distributed. By way of example, for each unit width

(corresponding to the carrier width) along the carrier-tool interface frontage there is but one I/O port. Hence, in conventional tools but a single carrier is interfaced per unit width of the tool front. This linear interface geometry is very limiting to tool load unload when the carriers being used are of reduced capacity. Further, the employment of pod advance plates for pod docking to I/O ports, in the conventional interfaces, typically involves pod registry along two planes (i.e. seating interface between pod and advance plate and port interface between pod and port), a condition which is overconstrained by its very nature with a corresponding deleterious affect on the rate of carrier supply to the tool. Also, the time involved in first registering a pod to the pod advance plate, and then having the pod advance plate bring the pod into contact/registry with the I/O port again impacts on the achievable rate of carrier supply. These are but some of the problems of conventional carrier-tool interfaces overcome by the exemplary embodiments as will be described in greater detail below.

Other examples of transport systems, carriers and openers may be found in U.S. Pat. Nos. 6,047,812; RE38,221 E; 6,461,094; 6,520,338; 6,726,429; 5,980,183; United States Patent Publications 2004/0062633, 2004/0081546, 2004/0081545; 2004/0076496 and pending Brooks Automation application Ser. No. 10/682,808 all of which are incorporated by reference herein in their entirety.

SUMMARY OF THE EXEMPLARY EMBODIMENTS

In accordance with an exemplary embodiment a substrate processing apparatus is provided. The apparatus has a casing, a low port interface and a carrier holding station. The casing has processing devices within for processing substrates. The load port interface is connected to the casing for loading substrates into the processing device. The carrier holding station is connected to the casing. The carrier holding station is adapted for holding at least one substrate transport carrier at the load port interface. The carrier holding station is arranged to provide a fast swap section for replacement of the substrate transport carrier from the carrier holding station.

In accordance with another exemplary embodiment, a substrate processing apparatus is provided. The apparatus has a casing, a load port interface, a carrier holding station, and a carrier loading and buffering system. The casing has a processing device within for processing substrates. The load port interface is connected to the casing for loading substrates into the processing device. The carrier holding station is connected to the casing. The carrier holding station is adapted for holding at least one substrate transport carrier at the load port interface. The carrier loading and buffering system communicates with the carrier holding station for loading and unloading the substrate transport carrier from the holding station. The carrier loading and buffering system interfaces with a first carrier transport system capable of moving the substrate transport carrier along a first transport path. The carrier loading and buffering system also interfaces with a second carrier transport system capable of moving the transport carrier along a second transport path.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other features of the present invention are explained in the following description, taken in connection with the accompanying drawings, wherein:

FIGS. **1-1**A are respectively schematic elevation and plan views of a substrate processing system incorporating features in accordance with an exemplary embodiment;

FIGS. **2**A-**2**B are respectively schematic front and side elevation views of a substrate processing system in accordance with another exemplary embodiment;

FIG. **3** is another schematic elevation view of a substrate processing system in accordance with another exemplary embodiment;

FIG. **3**A is a schematic plan view of an elevator transport of the substrate processing system in accordance with another exemplary embodiment;

FIGS. **4**A-**4**F are schematic elevation views each of which showing a substrate carrier, used with the processing system, in accordance with different exemplary embodiments;

FIG. **5**A is a schematic perspective view of a substrate carrier, used with the processing system, in accordance with still another exemplary embodiment;

FIGS. **5**B-**5**D are a schematic perspective and partial elevation views of a substrate carrier in accordance with yet other exemplary embodiments;

FIG. **6** is a schematic cross sectional view of a load port of the processing system in accordance with one exemplary embodiment interfaced to the substrate carrier shown in FIGS. **5**B-**5**D;

FIG. **7** is a schematic plan view of a processing tool carrier holding station of the processing system and a substrate carrier in accordance with an exemplary embodiment;

FIGS. **8**A-**8**B are respectively schematic elevation and plan views of a load port section of the processing system and substrate carriers in accordance with another exemplary embodiment;

FIGS. **9-10** are different schematic plan cross-sectional views of a load-port section and substrate carrier according to another exemplary embodiment;

FIGS. **11**, **11**A-**11**B are respectively a schematic perspective view and elevation views of a load port section and substrate carrier interface according to an exemplary embodiment;

FIGS. **12**A-**12**B are schematic elevation views of load port section and substrate carrier in docked and undocked positions according to an exemplary embodiment;

FIGS. **13**A-**13**E are other schematic partial elevation views and a perspective view of possible coupling between load port and carrier according to other exemplary embodiments;

FIG. **14** is a schematic elevation view of an active coupling between load port and carrier;

FIGS. **15**A-**15**C are perspective views of the carrier used with the coupling in FIG. **14** in accordance with different exemplary embodiments;

FIGS. **16**A-**16**E are other schematic partial elevation views of active coupling between load port and carrier according to still other exemplary embodiments;

FIG. **17** is a schematic plan view of an exemplary permanent/electromagnetic chuck;

FIG. **18** is a schematic elevation view of a processing tool and carrier of the processing system;

FIG. **18**A is a partial cross-sectional view of a load port section and carrier shown in FIG. **18**, and

FIG. **18**B is a schematic representation of a single four way sealing interface between the carrier, carrier door, load port door and load port frame of the processing tool and carrier in FIG. **18**;

FIGS. **19**A-**19**G are schematic views respectively showing a load port section, carrier/carrier door, and carrier door opener in accordance with different exemplary embodiments;

FIGS. **20**A-**20**C are schematic elevation views of a processing tool interface section with buffer and load port modules in different configuration as seen from one direction and

FIG. **20**D is another schematic elevation of the processing tool interface section, buffer and load port modules as seen from another direction;

FIGS. **21**A-**21**B are schematic plan and elevation views of processing tools and a carrier transport system in accordance with another exemplary embodiment;

FIG. **22** is a schematic elevation view of a processing tool, transport systems, transport vehicles and vehicle charge station according to another exemplary embodiment;

FIGS. **23**A-**23**B are schematic elevation views, as seen from different directions, of processing tool, carrier holding station and transport systems in accordance with another exemplary embodiment;

FIGS. **24**A-**24**C are respectively schematic top plane view, side elevation view of the processing tool load port section in FIG. **23**A and substrate carriers shown in different positions;

FIGS. **25**A-**25**B are schematic plan and perspective views of processing tools, transport systems, carriers and carrier vehicles according to another exemplary embodiment;

FIGS. **26**A-**26**B are schematic plan and perspective views of processing tools, transport systems, carriers and carrier vehicles according to another exemplary embodiment;

FIG. **27** is a schematic elevation view of a front end section, of a processing tool and carrier according to the prior art; and

FIGS. **28**A-**28**B are schematic elevation views from different directions of front end section of a processing tool and carriers according to other exemplary embodiments.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Referring to FIGS. **1-1**A, schematic elevation and plan views of a substrate processing system incorporating features of the disclosed embodiments, located in a fabrication facility or FAB are illustrated. Although the embodiments disclosed will be described with reference to the embodiments shown in the drawings, it should be understood that the embodiments disclosed can be embodied in many alternate forms of embodiments. In addition, any suitable size, shape or type of elements or materials could be used.

The substrate processing system **10** in the exemplary embodiment shown in FIGS. **1-1**A is representative of any suitable processing system and generally comprises processing tools **12** (one is shown for example purposes) transport system **6** and controller **300** (see also FIGS. **25**A-**25**B and **26**A-**26**B respectively plan and perspective views of substrate processing systems arranged in a FAB in accordance with other exemplary embodiments). The transport system **6** links the processing tools **12** in the FAB. The transport system **6** links the processing tools **12** in the FAB. The transport system **6** is capable of transporting substrate carriers C between the processing tools **12**. The processing tool **12** may have a loading/unloading interface **14** and buffer station **16**. The loading/unloading interface **14** holds carriers for loading/unloading substrates in the processing tool. The buffer station **16** provides a carrier buffer for carriers in transit between the loading/unloading station **14** and transport system **6**. A handling system **8** moves carrier between processing tool **12** and transport system **6**. The controller **300** is connected to the processing tool **12**, loading/unloading interface **14**, handling system **8** and transport system **6**. The handling system **8** handles substrate carriers C in the vicinity of a process tool **12** such that the carriers containing unprocessed wafers may be retrieved from a transportation system **6** and either moved directly to the loading/unloading interface **14** or optionally stored in the local queuing buffer **16**. The loading sequence is reversed to transition processed substrates back to the trans-

portation system **6**. The interface between loading/unloading interface **14** or buffer **16** and handling system **8** allows a "fast swap" of carriers C by shuttling the carriers to and from adjacent loading **14**A-**14**D, or storage positions **16**A-**16**D simultaneously, or in rapid succession as will be described in greater detail below. The handling system may allow any desired number of carrier transport systems to interface with the processing tool **12**. The loading/unloading interface **14** of the process tool **12** is capable of interfacing independently with each of multiple stacked carriers as will also be described in further detail below.

The transportation system **6** (a schematic plan view of which is shown in FIG. **1**A.) may comprise one or more transportation systems. The transportation system **6** may also be comprised of, for example, guided vehicles V (with or without integral hoists) and various types of conveyor systems or guideways G. The handling system **8** interfacing between the tool loading/unloading interface **14** and/or buffers station **16** may be configured to simultaneously interface with multiple transport systems of the same or different type, (e.g., vehicle- and conveyor-based transport systems) including those designed to transport conventional 25 wafer FOUPs. As seen in FIG. **1**, the guideways or conveyor systems G provide a path traversing a predetermined distance along which the vehicles V are transported. The guideway(s) may be of any suitable type (e.g. rail, track, moving belt, fixed surface) capable of providing guidance of any desired type to the vehicles V for the vehicles to traverse along the guideway (s) G. The guideway(s) may also be able to provide motive means to the vehicle. The vehicle V (one is shown in FIGS. **1**-**1**A but any desired number of vehicles V may move along guideway(s) G) may be capable of autonomous movement or may be moved by conveyor means on the guideway(s) G. Although guideway(s) G is illustrated as being located overhead relative to the processing station **12** and apparatus **10**, in alternate embodiments the guideway G may be located at any desired height relative to the apparatus **10** and processing station. As also seen in FIG. **1**A, the guideway(s) G is configured to provide an interface I with the handling system **8**. In this embodiment, the interface I has been illustrated schematically as being an opening O in the guideway(s), capable of allowing carriers C to pass through the guideway(s) when being transferred between handling system **8** (as will be described in greater detail below) serving tool **12** and vehicle (s) V. In alternate embodiments, the interface between the guideway and apparatus, where carriers may be loaded and unloaded from the apparatus, may have any other desired configuration (i.e. the apparatus may be offset from the guideway). FIGS. **2**A-**2**B are schematic elevation views respectively showing a processing tool **12** and transport system **6** from different (i.e. front and side) directions depict where the guideway is located at the floor elevation in accordance with another exemplary embodiment.

As noted before substrate processing tool or apparatus **12** illustrated in FIG. **1** is merely representative, and the features of the present invention as described with respect to the exemplary embodiments disclosed herein are equally applicable to any other suitable processing apparatus. The substrate processing apparatus may be of any desired type such as a substrate processing tool, a stocker or a sorter. One example of a suitable substrate processing tool is the GX series processing tool available from Brooks Automation, Inc. The processing tool **12** may have a casing or enclosure defining an interior space or chamber(s) in which the chamber atmosphere is capable of being controlled relative to the atmosphere exterior to the tool. For example, the tool **12** shown in FIG. **1** may be the environmental front end module (EFEM) of a processing tool, such as the aforementioned GX series tool. In general, the EFEM of a processing tool is joined to a processing chamber having an isolated atmosphere, such as inert gas or vacuum so that various semiconductor fabrication processes, such as material deposition, lithography, etching, substrate cleansing may be performed without potential contamination. Such a tool configuration is illustrated in the exemplary embodiment shown in FIG. **1**B, which will be described in greater detail below. The atmosphere in the processing tool chamber may be controlled in any desired manner. For example the processing tool **12** chamber may have fan filtration unit(s) (not shown) capable of introducing highly filtered (i.e. clean room quality) air into the chamber to establish and maintain a clean room atmosphere therein suitable for IC fabrication to line widths with 45 nm node or less. In alternate embodiments, the chamber may be capable of isolating the interior atmosphere from that exterior. In such embodiments, the chamber may hold an inert gas atmosphere or may hold a vacuum. As noted before and seen in FIG. **1**, the processing tool **12** has loading/unloading interface or load port **14** allowing substrates to be loaded and unloaded without compromising the interior atmosphere.

In the exemplary embodiment shown in FIG. **1**, the tool **12** has, a multi-dock loadport **14**. In the exemplary embodiment illustrated in FIG. **1**, the load port **14** is mated to the front face **12**F of the tool **12**. The term "front" is used for convenience to identify a side of the tool in a given reference frame and in alternate embodiments the load port may be located on any desired side (including top or bottom sides) of the tool. In the exemplary embodiment, for example when tool **12** represents an EFEM of a processing tool, the processing components within the tool (e.g. substrate transport robot, load locks, transport chamber, processing modules) may be arranged behind or to the rear (along an axis projecting into the panel) of the front face **12**F of the tool shown in FIG. **1**. The load port **14** may be integral to the face **12**F of the tool or may be a modular section (as will be describe below) attached to the tool face **12**F at a suitable mounting interface. The load port **14** generally has loading opening(s) therein, as will be described in greater detail below, through which substrates may be transferred into and out of the tool **12**. The load port LP may also have a closure(s) capable of closing or blocking the opening(s), at least sufficiently to maintain the chamber interior atmosphere uncompromised, when the opening(s) is otherwise exposed to the exterior atmosphere. Suitable examples of load ports are disclosed in U.S. Pat. No. 5,772,386, dated Jun. 30, 1998; U.S. Pat. No. 6,071,059, dated Jun. 6, 2000; U.S. Pat. No. 6,375,403, dated Apr. 23, 2002; U.S. Pat. No. 6,461,094, dated Oct. 8, 2002; U.S. Pat. No. 6,609,876, dated Aug. 26, 2003 and U.S. Pat. No. 6,837,663, dated Nov. 4, 2005 which are incorporated by reference herein in their entirety. The load port **14** may have a carrier holding or docking station that has a suitable support enabling a substrate carrier C to be docked to the load port so that substrates may be transferred between carrier and tool **12** along a transport path through one of the load port opening(s). In this exemplary embodiment, the load port **12** may have an associated docking station (as will also be described in greater detail below), for each loading opening. The loading opening and associated docking station may be arranged in loading opening/docking station pairs (i.e. one loading opening to one docking station). From hereon the term docking station will be used when referring to a loading opening/docking station path. The load port docking stations **14**A-**14**D of load port **14** are shown schematically in FIG. **1**. The carrier support (structure) **14**AF-**14**DF is shown to indicate the location of each docking station **14**A-**14**D (carriers C are located on some

docking stations supports). In this embodiment, the carrier support **14**AF-**14**DF are schematically shown as being located adjacent the loading opening (as may be realized, the area in FIG. **1** for or where the carriers C are located in the docking stations indicate the location of the loading opening) of the corresponding docking station. In alternate embodiments, the carrier support of the docking station may be located in any other desired position relative to the loading opening. For example, the carrier support for a given docking station may be offset from the loading opening and other load port loading openings of other docking stations may be located between carrier support and loading opening of the given docking station. As also seen in FIG. **1**, the docking stations **14**A-**14**D of load port **14** are substantially similar to each other. Each docking station **14**A-**14**D being capable of interfacing with similar carriers C (carriers having the same configuration and capacity). In alternate embodiments, the load port may have dissimilar docking stations, capable of interfacing with different configuration/capacity carriers.

As noted before, the load port **14** in this exemplary embodiment is a multi-dock load port with multiple docking stations **14**A-**14**D (four docking stations **14**A-**14**D are illustrated in FIG. **1** for example purposes, and in alternate embodiments more or fewer docking stations may be provided). In the embodiment shown, the docking stations **14**A-**14**D are offset vertically with respect to each other. The docking stations may be substantially aligned in a vertical row if desired, or may both horizontally and vertically offset in any desired arrangement such as diagonally aligned or staggered arrangement. In the exemplary embodiment, the docking stations **14**A-**14**D are sized to correspond to a conventional load port docking opening for a conventional 25 wafer FOUP. By way of example, in this embodiment, the load port **14** has four docking stations **14**A-**14**D, and the space envelope of the four docking stations including the space for having carriers C docked thereto is substantially the same as the space envelope of a single conventional 25 wafer FOUP load port as defined by the BOLTS-M interface standard (SEMI E63). The docking stations **14**A-**14**D of the load port **14** in the exemplary embodiment are capable of simultaneously handling a suitable number of reduced capacity carrier C that tool throughput is not compromised relative to conventional tools. In alternate embodiments, the number and size of load port docking stations may be varied as desired, and the load port docking area (encompassing all load port docking stations may have a space envelope of any desired size and shape). Further, the capability for fast swap replacement of carriers at the load port docking stations (as will be described below) improves the tool throughput.

Referring now to FIG. **5**A, there is shown a representative substrate carrier C that may be used with the processing system **10** in FIG. **1**. A suitable example of a substrate carrier having similar features as carrier C is disclosed in U.S. Patent Application titled Reduced Capacity Carrier and Method of Use; Ser. No. 11/207,231 filed Aug. 19, 2005, which is incorporated by reference herein in its entirety. The substrate carrier C generally has a casing **11**, with one or more substrate holding C**14** slots for the placement of substrates S therein. The substrates may be any desired substrate such as 200, 300, 450 mm (or any other diameter) semiconductor wafer, or reticle or flat panel for flat panel displays. The carrier casing is capable of holding a controlled atmosphere inside the carrier. In the exemplary embodiment shown in FIG. **5**A carrier **10** may have a side opening door **13** and features **16** for kinematic docking to the load port docking stations **14**A-**14**D that will open the carrier door as will be described more below. In alternate embodiments, other door and docking arrangements may be provided, such as flanges, guides or rollers for example. In other alternate embodiments, the carrier may be bottom opening. In this embodiments, the carrier also has features **20** allowing the carrier to be handled using an overhead hoist, similar or alternate material transport device. As seen in FIG. **5**A, the door **13** may be locked with dual (or single) cam mechanism and may have a hole and slot **22**A for pin locating, such as for example, in a similar fashion to conventional SEMI standard FOUP carriers.

Referring again to FIG. **11** as noted the tool **12** may have a buffer station **16** with a desired number of carrier buffer locations **16**A-**16**D. Four buffer locations **16**A-**16**D are shown in FIG. **1** for example purposes and in alternate embodiments the buffer station may have more of fewer buffer locations as desired. In this embodiment, each buffer location is capable of holding a substrate carrier C, though in alternate embodiments, any desired number of carriers may be buffered at a buffer location. The buffer station **16** may be located adjacent the load port **14** and within reach of the carrier handling system **20** linking the tool **12** and carrier transport system **6**. The buffer station **16** may be located between load port **14** and transport system **6**. For example, in the embodiment shown in FIG. **1**, the buffer station **16** is located between over head transport system **6** above and the load port **14** below the buffer station. Accordingly, the carrier handling system **20** transiting between load port **14** and transport system **6** is able to queue carriers in buffer locations **16**A-**16**D for loading in the load port docking stations and/or loading in the vehicles V of the transport system **6**. Referring now to FIG. **2**A-**2**B, the tool **12'** in this exemplary embodiment, which is similar to tool **12** except as noted, has a buffer station **16**B' located between the floor lever transport system **6'** below and load port **14'** above. In this exemplary embodiment, the tool **12'** has another buffer station **16**V'. The second buffer station **16**V' is located on the opposite (i.e. upper) side of the load port from (lower) buffer station **16**B' so that the load port **14'** is substantially sandwiched between buffer stations **16**V' **16**B'. In alternate embodiments, the buffer station may be located on an opposite side of the load port from the transport system. In the exemplary embodiments illustrated in FIGS. **1**-**1**A, and **2**A-**2**B, the buffer station are substantially aligned with the corresponding load ports (e.g. buffer station **16** and load port **14** and buffer stations **16**V', **16**B' and load port **14'**). In alternate embodiments, the buffer station and load port for a corresponding tool may be vertically offset from each other. As shown in FIG. **1**, in this exemplary embodiment the load port **14** (as well as buffer station **16**) is substantially aligned with transport vehicle load/unload station **6**S, a location where transport vehicles V on transport system **6** are positioned for transfer of carriers at interface I. Similarly, in the exemplary embodiment illustrated in FIGS. **2**A-**2**B, the load port **14'**, and buffer station **16**V', **16**B' are aligned with load/unload station **6**S' of transport system **6**. As may be further realized, the transport system **6**, **6'** in the exemplary embodiments provides a transport path that crosses the load port **14**, **14'** of the tool **12**, **12'**. Referring to FIG. **1**A, transport system **6** defines movement path for transport vehicle V, indicated by arrow M, that crosses over load port **14**. As may be realized, the transport vehicle V has a contact arrangement to guideway G that allows the vehicle to span opening O in the guideway and move over the opening and without interference with handling system **20** structure. Referring to FIGS. **2**A-**2**B, the movement path (indicated by arrow M' in FIG. **2**A) of vehicle V**1'** crosses through buffer station **16**B'. The buffer station **16**B' and handling system **20'** are arranged to allow vehicle V**1'** on transport system **6'** to move through the buffer station and handling system L e.g.

buffer station and handling system structure bridges across gap allowing passage of vehicle **V1**. In alternate embodiments, the transport system may be located so that the transport system guideways, or transport vehicle supported from and moving along the transport system guideways crosses through the docking stations for the load port of the processing tool.

Referring again to FIG. **1** the load port docking stations **14**A-**14**D may be loaded/unloaded by handling system **20**, or if desired manually. Similarly, the handling system **20** is capable of loading/unloading carriers from any desired buffer locations **16**A-**16**D. In this embodiment, the handling system **20** is located in front of the front face of tool **12** and adjacent the load port **14** and buffer section **16** in what may be referred to as a right-hand tool station version (i.e. when locking in the forward direction (i.e. out of face in FIG. **1**) from the tool front face, the load port/buffer station is to right to handling system). The load port **14**/buffer section **16** along with the handling system **20** may have a space envelope that occupies the space typically commensurate for two adjacent conventional load ports attached to a conventional EFEM system. In alternate embodiments the tool may have more loadport locations (as shown in phantom in FIG. **1** another load port location may be provided on the opposite side of the handling system) Tool stations may be constructed in right- and left-hand versions, whereby the elevator and loadport positions are reversed and additional capacity is available at the process tool. FIGS. **2**A-**2**B show an exemplary embodiment with a left-hand version.

Referring still to FIGS. **1**, **2**A-**2**B, the handling system in this embodiment is an elevator **20** that generally comprises a guideway **21** and carrier elevator(s) or lift(s) **22**. The elevator transfers carriers among several elevations to access the transportation system (e.g., over head transport system **6**, floor level transport system **6'**, conventional conveyor system (not shown), or manual delivery system), buffer nests **16**A-**16**D, and loadport docks **14**A-**14**D. In this embodiment, the guideway **21** is illustrated as being substantially vertically oriented, and extending from the (over head) transportation system **6** (or floor transport system **6'**) at least to the multi-dock load port **14**, **14'**. Referring also to FIG. **1**, in this exemplary embodiment the guideway **21** may also extend below the loadport **14** to a conveyor system CV or to a position for ergonomic manual loading. In alternate embodiments the guideway may be oriented as desired and may extend to any desired length. As seen best in FIG. **3**A (schematically illustrating a plan view of the elevator **20**), the guideway **21** generally comprises rails, tracks or belts **21**A, **21**B forming both a transport pathway and support for the carrier lifts **22**. In this embodiment, two rails **21**A, **22**B are shown for example purposes, and the guideway **21** may include any desired number of rails/guides. The rails **21**A, **21**B are illustrated schematically in the embodiment shown in FIG. **3**A as being similar and having a generally round cross-section, though the rails **21**A, **21**B may have dissimilar cross-sections, of any suitable shape to enable the lifts **22**A, **22**B to movably engage the rails so that the lifts are capable of bi-directional movement if desired along the guideway **21** in the direction indicated by arrow Z in FIG. **3**. In alternate embodiments, each rail **21**A, **21**B may comprise multiple substantially parallel rails.

FIG. **3**A shows two carrier lifts **22**A, **22**B, though any desired number of lifts may be used with guideway **21**. In this embodiment lift **22**A is mounted to traverse along guide rail **21**A, and lift **22**B is mounted to traverse along guiderail **21**B. As noted above, additional lifts similar to lifts **22**A, **22**B may be positioned to traverse along either or both rails **21**A, **21**B as desired. In this embodiment, lifts **22**A, **22**B are generally similar. Each lift has a base section **22**C, **22**C', holding the lift on the guiderail and a carrier gripper or carrier support section **22**D, **22**D', extending from the base section. The base section **22**C, **22**C', may have any desired configuration to engage rail **21**A, **21**B. A motor or other motive system (not shown) may be provided in the base section **22**C, **22**C' or the rail **21**A, **21**B or both. For example, the motive system may include any one of a electric servomotor, stepper motor, magnetic linear motor or other suitable actuator, such as pneumatic actuator, for moving the lift independently, and bidirectionally along rails **21**A, **21**B in the direction indicated by arrow Z in FIG. **3**. In alternate embodiments base sections **22**C, **22**C' may be moved on rails **21**A, **21**B by an endless loop/belt configuration. In that case, the lifts may be fixedly mounted to the belts to move substantially in unison with the belts. In that case, one base section, **22**C, may move in one direction (e.g. up) and the other base section, **22**C', may move in the opposite direction (e.g. down).

As seen in FIG. **3**A, the carrier support section **22**D, **22**D' of the lifts has support members such as support arms, tynes, fingers with a configuration to hold a carrier C on the lift. The configuration of the support section **22**D, **22**D' shown in FIG. **3**A is schematic and merely exemplary. In alternate embodiments the support section may have any other suitable arrangement capable of supporting a carrier and passing by each other when one or both lifts are empty. The carrier support section **22**D, **22**D' are shown in FIG. **3**A respectively in hold (or closed) and release (or open) positions. The support members of the carrier support section **22**D, **22**D' may be shaped to cooperate with desired features or surfaces CF of the carrier. Actuation of the support section **22**D, **22**D' may be effected by any suitable actuator such as electrical or pneumatic spring load solenoid. As seen in FIG. **3**A, lifts **22**A, **22**B respectively on rails **21**A, **21**B are capable of moving past each other with at least one carrier lift **22**A, **22**B holding a carrier C thereon. The carrier support section **22**D **22**D' may be configured to hold one or more carriers (e.g. in a vertical stack). This enables a fast swap of carriers at a given lift. As one carrier is realized and handed off from a given lift **21**A, **21**B, another carrier may be captured and grabbed by the same lift. In alternate embodiments, additional lifts may be added to the same guideways or to different guideways in the same column. The inclusion of additional lifts also may provide the ability to do the above-mentioned "fast swap", as well as providing a fault tolerance system through redundant carrier delivery mechanisms. As may be realized the carrier lifts **21**A, **21**B are able to traverse a common vertical right-of-way or space. For example, a full lift **22**A, and an empty lift **22**B, or two empty lifts may pass each other within the common right-of-way or space as shown in FIG. **3**A. The tool buffer control system **300** (see FIG. **3**) will shuttle one carrier C from its respective lift to a buffer shelf prior to the two lifts with carriers occupying the same right-of-way or space. In the exemplary embodiment shown in FIG. **3**, the guideways may be extended past the lowest carrier delivery location as described allowing a disabled lift to be pushed out of the way thus allowing the tool buffer to continue to cycle carriers through the system. The disabled carrier may be manually moved to the extended location or moved by another mechanical device such as an active lift. Alternatively, the guideway **21** could be continuous, as in a vertical carousel. Each lift may contain an active element (i.e., prime mover) capable of shuttling a carrier horizontally (in the direction indicated by arrow X in FIG. **3**) between the elevator column **20** and buffer locations or load port docking stations that may be passive.

Referring again to FIG. **3**, there is shown another exemplary embodiment of the elevator **22**M. Elevator **22**M in this embodiment has several platforms **22**M**1**-**22**M**4** (four platforms are shown for example but any desired number may be used) mounted with a fixed or adjustable vertical pitch to one or more lifting elements similar to lifts **22**A-**22**B. The platforms form vertically translating magazines for substrate carriers. The carrier platform pitch may substantially match that of the loadport docks **14**A-**14**D and buffer locations **16**A-**16**D. An active horizontal shuttling device may be deployed on each loadport dock station, buffer, location and/or carrier of the transportation system. The horizontal shuttling device may move the carriers from the transportation system to the load port and buffer locations and back again in the direction indicated respectively by arrows X_1, X_2 in FIG. **3**. Alternatively, the active horizontal shuttling elements could be grounded at elevations where transfers occur, to reduce the quantity of active elements employed. Still in another alternate embodiment, the tool station may have passive load port magazines, passive buffer nests, and use substrate carriers capable of autonomous mobility.

The carrier trajectory during the shuttling motion between loadport docks **14**A-**14**D, or buffer shelves **16**A-**16**D and the elevator system **20** may be accomplished in the horizontal plane. Picking and placing carriers by incorporating a small vertical motion of the lifts **21**, for example to engage and disengage passive nesting carrier to station or docking features (not shown) may be possible. To facilitate a vertical and horizontal shuttle, the minimum pitch between the nested carriers C may be increased. In the embodiment shown in FIGS. **1**-**3** shuttling of the carriers may be achieved by horizontally translating and constraining the nested carriers, if desired, by a movable latch or through the application of a retaining force, which causes the carrier to remain in a fixed, know location. The retaining force may be applied through magnetic attraction, fluid pressure, or other known means. Control of the motions of the lifts **22** during transport on elevator system **20** and during shuttling of carriers to and from the load port docks **14**A-**14**D or buffer stations **16**A-**16**D is performed from controller **300**.

Now referring to FIG. **4**, to accomplish the horizontal shuttling, means may be provided for support and guidance of the carriers, as well as transmission and coupling of the motive force. Support and guidance may be achieved for example by various arrangements of wheels, rails, skid plates, air bearings, magnetic forces, and the like as shown in the embodiments illustrated in FIGS. **4**A-**4**F. FIG. **4**A illustrates a carrier C**1** in accordance with an embodiment where the carrier frame CA has wheels CWV and CWH mounted thereon for providing both vertical and lateral support. In FIG. **4**B, an exemplary embodiment of the carrier C**2** is seated against wheels WV, WH (possibly mounted on a supporting track T depending from either the tool station **12** or the elevator **20**). In the exemplary embodiment illustrated in FIG. **4**C, skid plates SV, SH (mounted either to the carrier frame CA or the supporting structure on which the carrier is supported) movably support the carrier C**3**. In the exemplary embodiment shown in FIG. **4**D, the supporting track T**1** and/or the carrier frame includes air bearings or mag bearings BV, BH for supporting and guiding the carrier C**4**. In FIG. **4**E, the carrier C**5** rests on a movable conveyor T_c (belt or roller) and is guided laterally by side guide rails SGR as shown. In FIG. **4**F, the carrier C**6** frame has grooved wheels CWG mounted thereon riding on support rails TR. Linear motion can be developed by rotary motors driving belts, ropes, lead screws, robotic arm links, or skewed roller mechanisms, or by linear motors, pneumatic actuators, and the like. The linear motion so developed may be coupled to the carrier for example by mechanical interference, friction, magnetic force, or fluid pressure.

Referring now to FIG. **7**, there is shown a plan view of a carrier C positioned on a load port docking station **14**A (of the load port **14**, see FIGS. **1**-**3**) from the elevator **20** in accordance with an exemplary embodiment. The approach in accordance with the exemplary embodiment is to advance the carrier C from the side horizontally (in the direction indicated by arrow X) to a location relatively close to the backside of the loadport opening wall **12**W. A small gap G may be formed between the front face CFF of each carrier translated and the backside **12**W of the loadport opening wall. The position, shown in FIG. **7**, of the carrier C on the docking stations **14**A may be a registration or pre registration position from which the carrier C is registered as will be described below by closing gap G. In contacts, docking at the BOLTS plane is conventionally accomplished by gross carrier horizontal translation normal to the load port opening (e.g. in the direction indicated by arrow Y) which consumes time. Moreover, as previously described, front docking of conventional front opening carriers uses registration of the carrier along both its bottom (carrier to shuttle) and its front face (to seal the carrier load port interface and engage the carrier door). The resulting condition is overconstrained.

Referring now to FIG. **8**A there is shown an enlarged elevation view of a load port docking station LP**14**A, buffer locations B**16**A, B**16**B and carriers C in accordance with another exemplary embodiment. Carriers C are substantially the same as the carriers described before. The load port docking station LP **14**A is substantially similar to any one of the load port docking stations **14**A-**14**D in FIG. **1** or load port docking stations **14**A'-**14**B' shown in FIGS. **2**A-**2**B.

In the case of a front-opening carrier, using the front face for position registration as in the exemplary embodiment described herein overcomes a deficiency in conventional 300 mm FIMS (front opening interface mechanical standard) compatible interface, viz, concurrently controlling the horizontal docking interface and the vertical charging interface. This condition as noted before in conventional carriers is over constrained and is accommodated by maintaining a gap at the front interface between carrier and load port raising the potential of undesired contamination to the substrates load port and carrier.

As shown in FIG. **8**A, such a single-plane interface eliminates the bottom interface and associated shuttle mechanism of conventional systems, allowing the possibility of dense vertical packaging at loadports, or in storage/buffer locations (see for example FIGS. **2**A-**2**B). In the embodiment shown, supports or shelves LPS may be provided to rest the carrier(s) C but without registration features. To avoid generating over constraints on registration, the shelves and/or carrier legs may be arranged so that the carrier when seated freely on the shelf is pitched relative to the registered position. Registration of the carrier as will be described below results in the carrier being lifted off the shelf. Referring also to FIG. **8**B there is shown a plan view of carrier C interfaced to the load port docking station LP**14**. In this embodiment, the support shelf may define a registration feature for the carrier C, whereby the bottom of a front carrier structure C**6** is registered on a flat surface LPSF. The top or upper carrier portion C**8** is secured by a clamp mechanism LP**10** which supports the carrier in a cantilevered manner from the load port. In particular, as the clamp LP**10** is engaged, the rear of the carrier C is lifted from its passive support location. The front flat registration surface LPSF may also act as a contamination shield to lower interfaces. The clamp mechanism CP**10** has opposing clamp sec-

tions LP**12**, LP**14** as shown. The clamp sections are movable respectively between positions R**1**-R**4** (for clamp LP**12**) and position L**1**-L**2** (for clamp LP**14**) as seen clamp part LP**12** is capable of both rotation and transverse motion and clamp part LP**14** is capable of only transverse motion in the direction indicated by arrow Y in FIG. **11**. Clamp part LP**12** may be actuated with a four-bar linkage that causes clamp part LP**14** to engage and pull the carrier flange toward the port. To allow the carrier C to be placed by a mechanism (of the docking station or elevator) or by hand from the side in the direction indicated by arrow X, the clamp part LP**12**, retracts to the position labeled R**1**. The two clamping parts LP**12**, LP**14** may be tied together with a link (shown schematically as, feature LP**13** in FIG. **8**B) to enable a single drive axis. As seen in FIG. **8**B, the carrier C has kinematic features C**10**, C**11** that are respectively engaged by the closing clamp parts LP**12**, LP**14** to draw and hold the seating surface of the carrier face against a mating surface of the load port LP. The clamp mechanisms may be located on the sides of the port opening (as shown in FIG. **8**B) to minimize the potential of particulate contamination entering the interface area.

Another exemplary embodiment of the registration of a carrier C' to a load port docking station is shown in FIG. **9**. In this embodiment, the carrier C' is advanced and secured against the port using a compliant rear force. In the exemplary embodiment, an inflating bladder LP**10** is used to advance the carrier C' and secure it against the front interface. An adjacent (or same) bladder may have the capability of being evacuated to withdraw the carrier C' from the port. The bladder LP**70** has a vacuum cup LP**72** to secure the carrier C' while retracting. Any suitable compliant bladder or fluid actuated bellows device may be used. In alternate embodiments any other desired compliant actuation system may be used. This arrangement eliminates the conventional shuttle mechanism (1 axis) and conventional carrier hold-down (typically 2 axes) mechanisms of conventional FIMS loadports. As seen in FIG. **9** the front interface of the docking station in this embodiment includes an adjacent passive registration lead-in LP**40**. The lead-in is preferably located to the sides of the port to minimize the potential of particulate contamination entering the interface area. The front of the carrier C' in this embodiment has kinematic facets (seating surfaces) C**10'**, C**11'** located on the lateral sides of the carrier. The load port docking station lead in LP**40** has a complementing kinematic interface LP**60'** that is passive with guide and seating surfaces LP**62'**, LP**64'** to engage the mating kinematic facets C**10'**, C**11'** of the carrier thereby guiding and engaging the carrier so that the carrier is held cantilevered from the load port interface similar to carrier C' in FIG. **10**. Suitable seals (e.g. O-rings) in the load port opening perimeter ensure sealing between carrier casing and load port.

Referring now to FIG. **10**, there is shown a plan view of carrier C" interfaced to the load port docking station in accordance with another exemplary embodiment. In this embodiment a bellows LP**70"** is used to effect the latching and removal of the carrier door. In this embodiment advancement and registration of the carrier C" to the load port interface may be performed similarly to carrier C in FIG. **8**A-**8**B. As seen in FIG. **10** in this embodiment the carrier door C**13"** may be held in the frame of the carrier opening by a perimeter deflatable retainer C**02"** on the door C**13"** that engages a recess in the carrier frame (not shown) when the door is in the closed position and the retainer is inflated. In alternate embodiments, the door retainer may be any suitable pneumatic actuation members (e.g. pins, balls). In other alternate embodiments, the deflatable retainer of the carrier door may serve also as the seal between the door and carrier casing. In the exemplary embodiment shown the carrier opening frame may have a separate seal C**03"** to seal the interface between door C**13"** and carrier casing. As may be realized, registration of the carrier C" to the load port as previously described results in the bellows LP**70"** being brought into contact with the carrier door as shown in FIG. **13**.

Upon contact with the carrier door, the bellows is evacuated (by a suitable system) (not shown) to compress it, thereby securing and retracting the carrier door. Guiding registration pins LP**6"** on the port door LP**4"** may be used to maintain alignment of the carrier door C**13"** relative to the port door as it is retracted from, and returned to the carrier. An orifice or opening C**13**V" in the carrier door may allow vacuum to enter the door C**13"** and deflate the perimeter deflatable retainer of the door. The spring force of the bellows (or separate mechanical springs LP**8"** located on the port door) may be sized such that the deflatable retainer C**02"** collapses prior to the door C**13"** being removed. Upon venting (which may be filtered) of the port bellows LP**70"**, the spring force reinserts the door C**13"** into the carrier, and the collapsible retainer re-engages the carrier flange.

A representative interface between the carrier C**5** and a support face LPS for a load port docking station P**14**A (similar to docking station **14**A) according to this exemplary embodiment is shown in FIG. **11**. The carrier C**5** is shown in FIG. **11** in a position offset from the load port face for clarity. In the Figure, the load port support face LPS is shown as being on the load port face or plate that forms the substrate loading opening LPO of the load port. As may be realized, the load port support face may be any surface facing the interface side C**515** of the carrier. The interface side of the carrier C**515** has kinematic coupling features C**516** as will be described below. Referring now also to FIGS. **11**A, **11**B there is shown schematic elevation views of the carrier load port interface shown in FIG. **11**, with the carrier respectively in docked and undocked positions. In the docked position, the kinematic coupling features C**516** on the carrier and on the load port support face LPS are engaged to register and hold the carrier in the desired position and alignment relative to the load port opening LPO.

As may be realized, the kinematic coupling features may be of any desired configuration. One exemplary configuration is shown in FIGS. **12**A-**12**B which is a plan view of the carrier C**5**A in docked and undocked positions relative to the load port. In this embodiment the carrier has laterally projecting surfaces C**516**AF (for example on side flanges). The load port has projections that define complementing support faces LPSA. FIGS. **13**A-**13**B show another exemplary configuration of the kinematic coupling. In this embodiment, the carrier C**510**B may have a tapering guide notch C**516**B in a face facing the load port support surface LPSB. The load port support surface may have a complementing tapering pad section LPS**1** for engaging the notch C**516**B in the carrier. The projection on the load port may be fixed or may be spring loaded. The taper on the faces of the notch and projection are oriented to guide the carrier to the desired position. In FIG. **13**B, the tapering projection on the load port is shaped as a rounded pin. In the exemplary configuration shown in FIG. **13**C, the carrier has outer chamfered faces C**516**C that engage complementing angled faces in the load port. In the exemplary configuration shown in FIG. **130**, the carrier has a tapered bore C**516**D that is engaged by a complementing projection on the load port similar to projection LPS**1** in FIG. **13**A. FIG. **13**E shows the kinematic coupling C**516**E which has a male portion with engagement pins and a female portion

having a fixing hole (locating the male portion in two directions) and an elongated slot engaging the mating pin to float in one direction.

Referring now to FIG. **14**, there is shown an elevation view of a carrier C**610** registered to the load port LP with a electromagnetic coupling. In this embodiment, the carrier C**610** may have suitable magnetic material C**616** (such as stainless steel) included in or attached to the carrier casing. The load port be provided with a suitable permanent/electromagnetic chuck LPM. An example of a suitable permanent/electromagnetic chuck is disclosed in FIG. **17**, which generally has a permanent magnet or pair of permanent magnets positioned in a coil so that passage of an electric current through the coil switches the chuck on and off. The chuck is activated for carrier retention and deactivated to release the carrier. FIGS. **15**A-**15**C illustrate different exemplary embodiments of the carrier C**610**A, C**610**B, C**610**C with the magnetic material C**616**A, C**616**B, C**616**C in different locations as shown. As may be realized, magnetic retention does not involve moving parts resulting in a very clean interface with substantially no generation of contamination.

The kinematic coupling between carrier and load port may be an active mechanical coupling (similar to the coupling features illustrated in FIGS. **8**A, **8**B) Other exemplary embodiments of active mechanical couplings are shown in FIGS. **16**A-**16**E. In FIG. **16**A, the load port has rotating clamp section CP**750**A that engage features on the carrier C**710**A. In the embodiment shown in FIG. **16**B, the load port has an expandable device LP**750**B (e.g. a bladder) that is admitted into a recess/cavity on the carrier C**710**B. A suitable source of fluid (not shown) is connected to the bladder via lines provided in the load port docking station. The fluid introduced into the bladder and removed for expansion and contraction is controlled by the host controller. The carrier cavity C**716**B may have dovetailed faces which engage the surface of the expandable device when the device is expanded inside the cavity to draw the carrier against the load port, and register the carrier in the desired position. In the embodiment shown in FIG. **16**C, solenoid operated clamps LP **750**C on the load port are moved in an opposing direction against surface of the carrier C**710**C for registration. FIG. **16** shows another embodiment in which the load port docking station has member LP**750**OD defining a fulcrum for the carrier C**710**D and a stop surface LP**750**DS against which the carrier comes to rest when registered. The carrier has an engagement lip C**716**D that rests on the fulcrum provided by member LP**750**D, and the carrier is rotated from entry position C**710**D' until it rests against stop LP**750**DS. In the embodiment shown in FIG. **16**E, the coupling is arranged in a substantially opposite manner to that shown in FIG. **16**, with the fulcrum member LP**750**E on the bottom, and the carrier C**710**E rotated up into its registered position. In this embodiment, an active hook LP**750**EH is movably mounted on the load port to docking station structure engaged and hold the carrier in the registered position.

Upon registration of a carrier at a load port docking station is completed, it may be possible to proceed with opening the carrier to the load port in order to establish a transfer path for substrates between the carrier and tool through the load port. As may be realized, the carrier is opened by removal (or actuation) of the carrier door. Referring again to FIG. **1**, in this exemplary embodiment each docking stations **14**A-**14**D of the load port may have a carrier door opener, **14**AR-**14**DR capable of engaging the carrier door, of a carrier registered to the docking station as described above, and of removing the door. In this exemplary embodiment, each carrier door opener may be independently actuated (as will be described in greater detail below) to engage and remove the carrier door so that access to each carrier C docked at a load port docking station may be independently provided. In alternate embodiments, the carrier door openers of to or more docking stations (e.g. carrier door openers similar to openers **14**AR-**14**BR in FIG. **1**) may be slaved together to simultaneously engage and open the carrier arms of two or more docked carriers. As may be realized, the carrier door openers on the load port are generally conformal to the configuration of the carrier door to mate., engage and actuate any locking mechanism of the carrier door. For example, if carrier C has a door in accordance with the exemplary embodiment shown in FIG. **5**A (i.e. door with holes and slots **22**A for door opener pin locating and key engagement arranged pursuant to SEMI standards). The door opener mating interface (not shown) on the load port docking station **14**A-**14**D has locating pins and keys conforming to the mating holes and slots on the carrier door. Another exemplary embodiment of the carrier door opener of a representative load port docking station, similar to docking stations **14**A-**14**D in FIG. **1**, is shown in FIG. **10** described previously.

Referring now to FIGS. **5**B-**5**D there is shown a carrier C**810** in accordance with yet another exemplary embodiment. In this embodiment, the carrier has a door C**813**, (another door **813**A is shown, in this embodiment, on an opposite side of the carrier allowing the carrier to interface with either side to the docking station or allowing another device to interface with either side opening of the carrier). In alternate embodiments, the carrier may have more or fewer doors. The doors **813**, **813**A in this embodiment may be secured to the carrier casing with a locking system (C**818** with a chuck C**815** similar to the permanent/electro-magnetic chuck described before and shown in FIG. **17** acting in the carrier door. In this embodiment the magnetic material may be located in the door C**813**. The permanent/electro-magnetic chuck C**815** may be located in the carrier casing. As noted before, applying a current to the device, for example when the carrier is docked, activates/deactivates the chuck. FIG. **6** illustrates an embodiment in which the load port carrier door opener LPR has a permanent electromagnetic chuck LPR**2** to remove the carrier door C**813** from the carrier C**810** docked to the load port docking station. Except as otherwise noted, the load port docking station shown in FIG. **6** is similar to docking stations **14**A-**14**D shown in FIG. **1**. The permanent electromagnetic chuck LPR**2** in the carrier door is substantially similar to the permanent electromagnetic chuck shown in FIG. **17**. Registration of the carrier C**810** to the docking station positions the carrier door C**813** sufficiently close to the LPR for the chuck LPR**2** to capture the door when activated. Seals may be provided to seal the interface between carrier door and door opener LPR as will be described in more detail below. In alternate embodiments, the carrier door may be in contact with the door opener so that activation of the door opener chuck (similar to chuck LPR**2**) does not cause relative movement between carrier door and door opener. In this exemplary embodiment, activation of the door opener chuck LPR**2**, as well as the carrier chuck C**815**, is effected by controller **300** (see FIG. **1**) to occur substantially simultaneous with or at some suitable time before the carrier chuck C**815** is deactivated. Replacement of the carrier door C**813** on the carrier may occur in a substantially similar but reverse manner with the carrier chuck C**815** being activated with or prior to deactivation of the carrier door opener chuck LPR**2**. In the exemplary embodiment shown in FIG. **6**, the docking station may have a coupling LP**40** for providing power and communication to the registered carrier C**810**. Although shown as having

a mechanical interface (e.g. plug), the carrier coupling may be of any suitable type including wireless RF or optical.

As may be realized, it is highly desired that contamination of either the interior of tool **12** or the interior of the carrier(s) be avoided when the carriers are opened to the tool. Sources of possible contamination to the tool are from outside atmosphere, carrier exterior or carrier interior (as the carrier may be holding a different and undesired gas species, for example a gas species that entered the carrier when opened to a previous tool during the wafer FAB process. Conversely, sources of carrier contamination may be from the outside atmosphere and load port exterior. Referring now to FIG. **18**, there is again shown a schematic representative tool **1012** (similar to processing tool **12** in FIG. **1** that has a mini-environment ME provided for the interface between processing modules and substrate carriers C**1010**. As noted before with reference to tool **12** in FIG. **1**, the mini-environment ME may have a controlled atmosphere with a desired gas species/or mix (e.g. N2, AR, AR/02, very dry air that is different from the outside atmosphere. The atmosphere inside the mini-environment may also be different from the atmosphere inside the carrier C**1010**. The mini-environment is illustrated in this exemplary embodiment as having a load port with a single representative docking station LP**1014**. The docking station is generally similar to docking stations **14**A-**14**D in FIG. **4**. FIG. **18**A is a partial cross-sectional view of the load port docking station LP**1014** and carrier (**1010** registered thereto. In this embodiment, the load port docking station has a carrier door remover LPR that substantially closes the substrate transport opening in the load port. Suitable seals **1116** between load port frame and door remover LPR seal the mini-environment from the exterior. In alternate embodiments, the door remover may not close the load port opening. Also the gas pressure P**2** inside the mini-environment may be greater than outside pressure P**3** or carrier pressure P**4**. By sealing the carrier face to the mini-environment, wafer exposure to potentially offensive gas species (e.g. outside atmosphere, undesired gas species from carrier interior) may be controlled as shown in FIG. **18**. The sealing may be accomplished with multiple seals (e.g. carrier to carrier door seal **1112**, carrier to load port seal **1110**, carrier door to load port door remover seal **1114** and load port door remover to load port seal **1116** as shown in FIG. **25**A) or a single integrated seal. As noted before, a key (such as may be used with a carrier door as shown in FIG. **5**A) may reside in the interface between the carrier and the minienvironment load port docking station, and the carrier C**1010** being both (a) front locating and (b) front sealing whereby the locating and engagement action of the carrier also seals the carrier to the load port docking station and hence the mini-environment itself. Trapped air in the interface between carrier and load port may be eliminated by zero-volume sealing (see FIG. **18**B which schematically shows the zero volume interfaces between carrier C**1010**, carrier door C**1013**, load port door remover LPR and load port LP **1014**. Trapped air in the case of the non-zero volume interface shown in FIG. **18**A, may be eliminated by purging, such as where a valve is cracked in a purge conduit **1118** of the load port docking station from the minienvironment and the mini-environment gas species introduced into the void VO (defined between door remover LPR and carrier door C**108**) and evacuated as with an exhaust valve **1120**. In the exemplary embodiment, there may be a dedicated purge conduit, though alternatively the purge conduit and valve from the mini-environment may be formed by the seal **1116** between door remover and frame which may be cracked to purge the void VO. The interior region of the carrier **1010** may also be purged, such as for example by exposing the interior of the carrier to the gas species (e.g. cracking seal **1112**, first) before the seal **1116** between the port door remover LPR and mini-environment load port LP**1014** is opened. Here, when the carrier interior is exposed to the minienvironment, the species that the wafer is exposed to remains the same where the carrier contains that species. In this manner, a carrier may be moved from tool to tool with the gas species that the wafers are being exposed to is effectively controlled. In alternate embodiments, different surfaces may be heated, cooled, charged or otherwise applied to further control particle migration and attraction.

FIGS. **19**A-**19**G show two carriers C_1-C_2, and carrier door removing mechanisms or representative load port docking stations are show in accordance with a number of exemplary embodiments. Though two carriers and docking stations **14**A, **14**B are shown, it is understood that these features are applicable to one or more of the docking stations of the load port.

Referring to FIG. **19**A, door opening and closing may be accomplished by using 1 to n mechanisms, similar to mechanisms **30**A, **30**B where n is the number of docking stations per loadport. Deploying one door opener **30**A, **30**B at every docking station **14**A, **14**B permits complete flexibility in the wafer access sequence. This is shown in FIG. **19**A. In this embodiment, each door opening and closing mechanism **30**A, **30**B may service a specific carrier C_1-C_2 at a corresponding load-port docking station. Door opener mechanisms **30**A, **30**B are substantially similar. Each door opener mechanism **30**A, **30**B may have interlock and engagement features, such as locator pins, engagement keys, to mate with the doors CD**1**, CD**2** of the carriers. As seen in FIG. **19**A, the door opener mechanism may include a closure **30**C capable of closing or at least partially blocking the loadport interface opening **14**O. The door opener mechanism **30**A, **30**B is actuable as will be described, from a blocking position (not shown) to an open position shown in FIG. **19**A. When in the blocking position, the door mechanism is able to engage the carrier door CD**1**, CD**2** with the engagement features. Further, the engagement features are operable, such as by, servomotor, or pneumatic actuator, to cause release as well as engagement of the locks (not shown) holding the door CD**1** on the carrier. The engagement features, may also be operable to engage or lock the carrier door CD**1** to the door opener mechanism **30**A, or dedicated locks (e.g. vacuum) may be provided to hold the carrier door onto the door mechanism. Each door opener mechanism **30**A, **30**B may have a suitable actuator **30**, such as a motor or pneumatic actuator for independently moving each door opener mechanism **30**A, **30**B between blocking and open positions. As may be realized, in the open position, the door opener mechanism provides substantially unrestricted access for transport of substrates to and from the carrier through the load port. In the exemplary embodiment shown in FIG. **19**A, the carrier door CD**1** is pivoted, such as for example on a hinge, through an arc θ between blocking and open positions. FIGS. **19**C-**19**D, which respectively are schematic top plan and front elevation views of door openers of load port docking stations illustrates another exemplary embodiment. In this exemplary embodiment, each carrier door CD**1**, CD**2** is translated by corresponding door opener mechanisms **30**A', **30**B' in a plane, defined by directions indicated by arrows X and Y in FIG. **19**C. As seen in FIGS. **19**C-**19**D, the door openers **30**A', **30**B' in this embodiment are connected to a suitable actuation mechanism (such as pneumatic or electric drive) capable of generating the substantially linear motions of the door openers in the directions indicated by arrows X, Y in FIG. **19**C. As may be realized, direction X is oriented out of plane with respect to the face plane **12**W of the load port (defining the load port opening). The Y direction is oriented laterally along the load port face plane **12**W. The

movement directions X, Y may not be respectively orthogonal or parallel to the face plane, and may not be orthogonal relative to each other. As in the embodiment illustrated in FIG. **19**A, and as shown in FIGS. **19**C-**19**D, the door openers may be actuated independently of each other, and the movement paths of the door openers and hence of the carrier doors CD**1'** CD**2'**, between open and closed positions do not lapse interference between either the door remover or carrier door and substrate transport paths through the substrate loading openings **140** of other load port docking stations. Thus, in this embodiment access to each carrier at a docking station may be independently provided.

In FIGS. **19**E-**19**F, each door CD**1'''**, CD**2'''**, CD**3'''** is pivoted by the door opener mechanism **30**A''', **30**B''', **30**C''' within a plane substantially parallel to the backplane **12***w* of the loadport. In this exemplary embodiment, the respective door opener mechanism **30**A''', **30**B''', **30**C''' may be positioned on opposite sides of the loadport opening **14**O as shown. Each opener mechanism pivots the corresponding doors CD**1'''**, CD**2'''**, CD**3'''** in opposite directions (mechanisms **30**A, **30**C rotate counterclockwise and mechanism **30**B rotates clockwise). In alternate embodiments, both mechanisms may rotate the doors in the same direction. In this embodiment, the door opener mechanism may displace the door by translation in the direction indicated by arrows X**1**, X**2**, X**3** to a position where the doors may be freely rotated so as not to interfere with each other. In the exemplary embodiment shown in FIG. **19**E, the door opener mechanism is capable of moving the door CD**1''** from the blocking position to a location S in front of a closed carrier, or a loadport opening where no carrier is located.

In alternate embodiments a reduced number of door remover mechanisms (i.e., fewer mechanism than openings) may be employed, each capable of performing door opening and closing at one or more dock positions. The exemplary embodiment of the tool station illustrated in FIG. **19**B deploys a single mechanism **130** at each loadport **14** (see FIG. **1**) that can selectively engage **1** to n carrier doors such that any combination may be opened and/or closed simultaneously. In this case, the mechanism **130** has multiple door engagement stations with features for engaging carrier doors. The features **130**A, **130**B may be selectably operated to lock or unlock carrier doors (e.g. simultaneously lock and unlock different doors, or lock/unlock doors while other doors are not engaged).

It is envisioned that the door removal process may be similar to the process currently used to remove a standard 13 or 25 substrate FOUP. However, other door opening mechanisms and methods are disclosed. For example, the carrier door may swing open from top to bottom exposing the substrates to a robotic manipulator. The mechanism may have to unlatch a door-closing latch and rotate the door down to open the carrier and rotate the door up and latch the door-closing latch to close the carrier. Additionally, the doors may be blocked by sealed balloon interface in which the opening and closing mechanism may be controlled by a gas delivery and removal system that blows up the balloon seal to close the carrier and evacuates the gas to open the carrier.

A consequence of deploying reduced wafer-count carriers is an increase in the total quantity of carriers, and in the frequency of docking/undocking events throughout the factory. As such, the overall complexity of the control software for the tool buffer system is significantly increased. Additionally, the resulting increase in demand for communication with factory control software (particularly the downloading of recipes and parameters) is accompanied by an increased sensitivity to communication latency, since the process time per carrier is similarly reduced. To ensure that wafer processing is not delayed, instructions can be dispatched to the tool in advance of the carrier and verified upon its arrival. To accommodate such a scheme, the carriers C in the exemplary embodiments may be considered "smart" carriers which contain on-board intelligence, such as a processor or memory module (not shown), that carry such information for the current tool and, possibly, future process steps. Hardware such as controller **300** (see FIG. **1**) is deployed throughout the system to read and write such data to and from the carrier. Communication time is decoupled from transfer time by replacing a serial data exchange with a single time-critical transfer of information (e.g., between carrier and tool) preceded and followed by background updates to the host.

Referring to FIGS. **23**A-**23**B, there is shown a schematic front and side elevation views of tool station **112** and overhead transport system **100**T in accordance with yet another exemplary embodiment. As seen in FIGS. **23**A-**23**B, tool station **112** is substantially similar to the above-described tool station **12** but utilizing an overhead hoist **100**T, rather than an elevator **20**, to effect the vertical translation of the carriers. The loading hoists may be affixed to over head track vehicles **100**V as part of the transportation system, or alternatively as part of a "gantry" crane system **100**T dedicated to servicing one or more tools. In the latter embodiment, hoists may be added as desired to provide redundancy and match demand.

FIG. **23**A shows a carrier magazine **100**C that is raised and lowered by an overhead hoist **100**H to interface with docking stations **114**A-**114**D, buffer locations **116**A-**116**B, and the transportation system **100**T. A novel approach is desired to manage the reaction forces arising from transverse (indicated by arrow Y) carrier motion at the end of a flexible hoist. In this exemplary embodiment the carrier magazine **100**M is docked to the loadport docks **114**A-**114**D with a mechanical latch, magnetic attraction, or fluid pressure or other actuable supporting system **100**L (shown schematically in FIG. **23**A). The latching means **100**L provides the support to offset the reaction forces that arise while a carrier is transported to/from the lifting magazine **100**M and the load port docking stations **114**A-**114**D (in a similar manner the carrier magazine may be stably held for lateral carrier transport to the buffer location supports **116**A-**116**B). Alternatively, a counteracting force could be generated by a moving mass **100**B or gyroscope to compensate for the lateral motion applied to the lifting magazine during the carrier transport. In yet other alternate embodiments the flexible hoist may be replaced with substantially rigid reeled members. The rigid members from the hoist to the lifting magazine offset the reaction forces that arise while a carrier is transported to/from the lifting magazine and the load port docking stations.

Another way the exemplary embodiment enables hoist-based loading is to make all docking positions accessible from above. Referring to FIGS. **24**A-**24**C, there is shown a loadport **214** with multiple docking levels (shelves) **214**A-**214**C capable of presenting carriers for access from directly overhead as indicated respectively by arrows Z**1**-Z**3**. Loadports may have an "undocked" position where carriers are loaded and unloaded, offset by gap G, and a "docked" position, where wafers are accessed (FIGS. **24**A, **24**C). In all (e.g. dock positions **214**B-**214**C) but the topmost dock position **214**A, a swing-out motion indicated by reference arrows **42**, **43** move carriers from the docked to the undocked position providing top access. The loadport docking shelves **214**B, **214**C rotate or horizontally traverse Y**2**, Y**3** to a position in which the OHT can delivery a carrier. After the carrier **200**C is place onto the docking shelf **214**C-**214**B, the shelf may be rotated or horizontally traversed within the loadport opening

boundary. In one embodiment, the hoist has a mechanism such as previously described that allows for a swap of a processed carrier with an unprocessed carrier.

If additional storage of carriers is desired (i.e., bulk factory storage, as distinct from local tool buffering), the loading system described above could be deployed remotely with extra buffer positions replacing the loadport. The buffer positions may be stand-alone racks that may be secured from the floor, ceiling, or attached to a process tool. Buffer positions may also be racks that are located directly below or attached to the side of a transport system track.

In accordance with another exemplary embodiment, the load port(s) such as load port **14** in FIG. **1**), the buffer (e.g. buffer **16** in FIG. **1**) and handling system **20** (e.g. handling system **20** in FIG. **1**) may be modular. FIGS. **20**A-**20**C shows front views of three exemplary arrangements of load port modules **2014**, buffer modules **2016** and handling system modules **2020**. Except as otherwise noted the load port modules **2014**, buffer modules **2016** and handling system module are substantially similar to the load port **14**, buffer **16** and handling system **20** described before and shown in FIG. **1**. FIG. **20**A shows load port and buffers modules to the left (facing out from tool BOLTS plane) of the handling system module. In alternate embodiments the arrangement may be mirror opposite to that shown in FIG. **20**A. Also buffers may just be located above or just below the load port. FIGS. **9**B and **9**C also show load port modules **2014** and buffer modules **2016**U, **2016**B located on both sides of the handling module **2020**. In alternate embodiments, the load port module may be on one side and the buffer module on the other side of the handling module. The modules **2014**, **2016**U, **2016**B, **2020** may be related to each other at the module interface **2022**X. The module interface **2022**X defines where each module is mounted and registered so that each module is related to another module by reference to a suitable interface datum **2026** (e.g. the FAB floor or other suitable datum). The handling module may also be registered relative to a payload transport system **2006** (similar to transport system **6** in FIG. **1**) located at any elevation between the floor and ceiling of the installation. The modules may be assembled in any desired order. One exemplary method to attach the modules may be that the load port module **2014** may be mounted to the BOLTS plane of a tool, (see FIG. **9**D, the handling module **2020** to the load port module and the buffer modules **2016**V, **2016**B to the handling module **2020**. In accordance with another exemplary embodiment, the modules may be pre-assembled to each other then mounted as an assembly **2024** to the BOLTS plane. Once in the FAB, any module may be changed to accommodate a change in the operational parameters of the system. The Interface datum **2026** may be used for "factory" teaching of the handling system of module **2020** and controller **300**. All modules are individually configurable for accommodating any of a number of predetermined payloads that conform to different operating scenarios. These differences might be in the vertical pitch of payloads at load port docking stations or buffer locations or the reach of the payload manipulator (not shown) mounted to the handling system. The manipulator might also employ a different "end-effector" to accommodate the particular payload. The end effector could be a paddle, a fork, a mechanical gripper, magnetic chuck, or any such device particular to its purpose. Since variable configurations are possible, the handling system module may be self teaching relative to the interface datum. Once a configuration of modules is assembled into a system, an instruction given to the controller **300** by means of a suitable interface (touch screen or equal) may cause the handling system to run through a self teaching routine that establishes the desired positioning and sequencing for the system configuration. This may be achieved in numerous ways such as by the application of a routine that uses sensors such as photo-electric types to determine the particular relationship of modules. Once this relational information is collected, pre-taught routines existing in the controller may take over for the manipulation of payload within the system.

Referring now to FIGS. **21**A-**21**B there is shown plan and elevation views of tools or tool stations **2012**, **2012'** connected by a shunt transport system or shunt **2004** in accordance with another exemplary embodiment. The tool stations **2012**, **2012'** are similar generally to each other and to tool station **12** in FIG. **1**. Each tool station **2012**, **2012'** may have buffer **2016**V, **2016**V' load port **2014**, **2014'** and handling system **2020**, **2020'**. As may be realized, the arrangement of the buffer, load port and handling system may be different at each tool station. The shunt may be arranged to connect two or more tool stations **2012**, **2012'** and in particular two or more systems of the connected stations. For example, the shunt may connect the buffer of one tool station to the buffer, load port and or handling system or another tool station, and vice versa. The shunt may interconnect stations at any number of tool stations in any desired combinations. The shunt **2004** may be a dedicated unidirectional or bi-directional carrier transfer device such as a section of accumulating conveyor. Alternately, the shunt **2004** may be provided by any vehicle- or conveyor-based transport device (including overhead transports OHT's) deployed in parallel with the main carrier transport system between and among any number of tools. FIG. **21**B shows one buffer level connection however multiple levels may be connected. The shunt **2004** may also register to the aforementioned interface datum (see FIG. **20**B) of each tool station for self teaching purposes.

FIG. **22** shows another tool station **2212** (with the load port **2014**, buffer **2016**B) and transport vehicles in position for loading, unloading, or queued for access to handling system **2220**. Vehicles powered by stored energy (batteries and/or ultra-capacitors) will recharge at charging zones **2240** within the space envelope of the buffer/load port or handling system at the tool station. The charging may be accomplished by contact or non-contact (inductive) means from below, above, or beside the vehicle as well as upstream or downstream of that point. The charging zone may be located as desired so that vehicles V may charge while queued, unloading, or loading, making use of internal processing time. Vehicle charging in these locations will not interfere with other vehicle traffic. Charging power supplies and electronics (not shown) may be packaged in modular form to allow installation as a module in the desired location.

FIG. **25**A shows an example plan view of a FAB layout with tool stations **2512** substantially similar to tool station **12**, **12'** described before and shown in FIGS. **1**, **2**A-**2**B. In this embodiment, the load port buffer, and elevator may be located in front of the tool station and occupy, for example approximately 18 inches of space in an aisle. FIG. **26**A shows a plan view layout of another exemplary embodiment that reorients the load port **2614**, buffer **2616** and elevator **2620** of the tool **2612** to the side of the tool station, allowing reduction of the aisle width by the depth of the load-port; (e.g. about 18 inches per side; in a dual aisle a total of about 36 inch. In this embodiment, the load port, buffer and handling system are in line with the tool. The load port and buffer is interposed between tool and handling system. If a front opening carrier C is used in this layout the payload may be reoriented so that the carrier C**13** door faced the side of the EFEM. In this layout access for manual loading of a tool may be done from the tool chase area leaving the aisles free for low elevation vehicle

traffic, free of operator interference. As shown in FIG. **26**A a vehicle V will carry its payload (e.g. carrier C) in the proper orientation. FIGS. **25**B and **26**B are isometric views of each layout described.

As shown in FIG. **28**A, load port **2814** of tool station **2812** may have port status indicators **2860**, such as LEDs, may be incorporated on loadport modules to display port states including carrier present, carrier nested, busy, ready, and the like. FIG. **28**B shows an arrangement in accordance with another exemplary embodiment whereby the status indication resides on the carrier C itself, rather than the loadport module **2814**. The status may be generated locally (e.g., sensors that detect proper nesting reside within the carrier) or transmitted to the carrier from the loadport as with wireless transmission, or mechanical coupling. Similarly, power to illuminate the display may be supplied by the loadport or stored as electrical energy within the carrier. FIG. **27** illustrates status indicator of a convention EFEM.

It should be understood that the foregoing description is only illustrative of the invention. Various alternatives and modifications can be devised by those skilled in the art without departing from the invention. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

The invention claimed is:

1. A substrate processing apparatus comprising:

a casing comprising a processing device configured to process substrates;

a load port interface configured to load substrates into the processing device;

a carrier holding station disposed at the load port interface and configured to hold one or more first substrate transport carriers, so that the one or more first substrate transport carriers configured to be held by the carrier holding station are capable of being coupled to the load port interface without lifting the one or more first substrate transport carriers off the carrier holding station, wherein the carrier holding station is configured to provide a substantially simultaneous swap section for substantially simultaneous replacement of the one or more first substrate transport carriers from the carrier holding station with one or more second substrate transport carriers from a handling system; and

the handling system comprising a vertically oriented guideway along which an elevator system travels, the elevator system having a plurality of lifts, with the plurality of lifts disposed perpendicular to the vertically oriented guideway and with the plurality of lifts offset vertically with respect to each other,

wherein the vertically oriented guideway and the plurality of lifts are configured to transfer the one or more first substrate transport carriers and the one or more second substrate transport carriers to and from a transport system at a first elevation and the carrier holding station at a second elevation.

2. The apparatus of claim **1**, wherein the elevator system is configured to link the carrier holding station to a the transport system and is configured to transfer the one or more first substrate transport carriers between the carrier holding station and the transport system.

3. The apparatus of claim **1**, wherein the elevator system comprises a frame fixedly connected to the casing.

4. A substrate processing apparatus comprising:

a casing comprising a processing device configured to process substrates;

a load port interface configured to load substrates into the processing device;

a carrier holding station configured to hold at least one substrate transport carrier at the load port interface;

a carrier loading and buffering system configured to communicate with the carrier holding station and configured to load and unload the at least one substrate transport carrier from the carrier holding station, wherein the carrier loading and buffering system is configured to interface with a first carrier transport system configured to move the at least one substrate transport carrier from a first substrate processing apparatus to a second substrate processing apparatus along a first transport path, and wherein the carrier loading and buffering system is also configured to interface with a second carrier transport system configured to move the at least one substrate transport carrier from the first substrate processing apparatus to the second substrate processing apparatus along a second transport path; and

a handling system comprising a vertically oriented guideway along which an elevator system travels, the elevator system having a plurality of lifts, with the plurality of lifts disposed perpendicular to the vertically oriented guideway and with the plurality of lifts offset vertically with respect to each other,

wherein the vertically oriented guideway and the plurality of lifts are configured to transfer the at least one substrate transport carrier to and from a third carrier transport system at a first elevation and the carrier holding station at a second elevation.

5. The apparatus of claim **4**, wherein the first and second carrier transport systems are offset relative to each other.

6. The apparatus of claim **4**, wherein the loading and buffering system is configured to span between the first and second carrier transport systems to join the first and second carrier transport systems to each other.

7. The apparatus claim **4**, wherein the carrier loading and buffering system comprises storage stations, each of which is configured for storing the at least one substrate transport carrier,

wherein the carrier loading and buffering system comprises a carrier transfer interface configured to interface with one of more of the first carrier transport system and the second carrier transport system,

wherein the carrier transfer interface is configured to transfer the at least one substrate transport carrier between the carrier loading and buffering system and one or more of the first carrier transport system and the second carrier transport system, and

wherein the carrier transfer interface comprises an interface distinct from each of the storage stations.

8. The apparatus of claim **4**, wherein the carrier loading and buffering system comprises storage stations, each of which is configured for storing the at least one substrate transport carrier,

wherein the carrier loading and buffering system comprises a carrier transfer interface configured to interface with one or more of the first carrier transport system and the second carrier transport system,

wherein the carrier transfer interface is configured to transfer the at least one substrate transport carrier between the carrier loading and buffering system and one or more of the first carrier transport system and the second carrier transport system, and

wherein the carrier transfer interface comprises an interface independent from one of the storage stations of the carrier loading and buffering system.

9. A substrate processing apparatus comprising:

a casing comprising a processing device configured to process substrates;

a load port interface configured to load substrates into the processing device, the load port interface comprising a number of stacked openings, with a first stacked opening defining a corresponding substrate transport path through the first stacked opening and with the first stacked opening comprising a first movable closure configured to block the corresponding substrate transport path; and

a carrier holding station configured to hold at least one substrate transport carrier at the load port interface and configured to load and unload substrates;

wherein the first moveable closure is configured to be independently movable, relative to a second moveable closure of a second stack opening, from a blocked position, in which the first moveable closure is configured to block the corresponding substrate transport path, to an unblocked position, in which the first moveable closure is configured to not block the corresponding substrate transport path,

wherein the number of stacked openings collectively comprise a size that corresponds to a load port opening configured to hold a twenty-five substrate, side opening transport carrier; and

a handling system comprising a vertically oriented guideway along which an elevator system travels, the elevator system having a plurality of lifts, with the plurality of lifts disposed perpendicular to the vertically oriented guideway and with the plurality of lifts offset vertically with respect to each other,

wherein the vertically oriented guideway and the plurality of lifts are configured to transfer the at least one substrate transport carrier to and from a carrier transport system at a first elevation and the carrier holding station at a second elevation.

10. The apparatus of claim **9**, wherein the corresponding transport path comprises a first corresponding transport path and wherein the first moveable closure is configured to be independently moveable between blocked and unblocked positions so that the first corresponding transport path through the first stacked opening can be blocked and unblocked independently of a second substrate transport path of the second stacked opening.

11. The apparatus of claim **9**, wherein the corresponding transport path comprises a first corresponding transport path and wherein the load port interface defines a second, different substrate transport path with a path that is independent from the first substrate transport path and from the first moveable closure.

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